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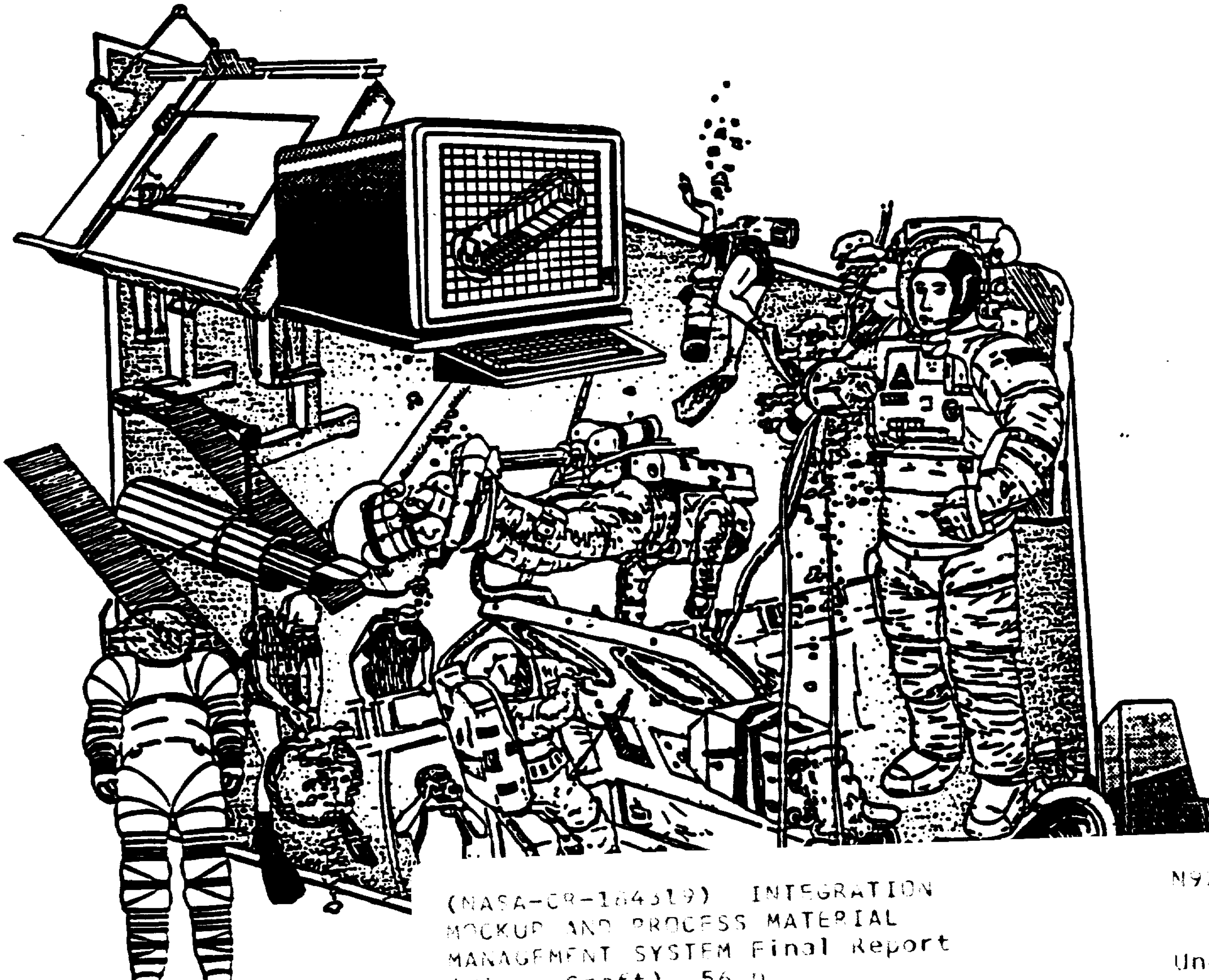

(NASA-CR-184319) INTEGRATION MOCKUP AND PROCESS MATERIAL MANAGEMENT SYSTEM Final Report (Micro Craft) 56 p

N92-30754

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Final Report on Contract NAS8-36412
Integration Mockup & Process Material Management System

MICRO CRAFT INCORPORATED

HUNTSVILLE DIVISION

FINAL REPORT ON CONTRACT

NAS8-36412

INTEGRATION MOCKUP

AND

PROCESS MATERIAL MANAGEMENT SYSTEM

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GENERAL MANAGER

HUNTSVILLE DIVISION

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INTRODUCTION

This report describes the work performed by Micro Craft, Inc. to support the NASA contract NAS8-36412 to define and develop a full scale Space Station mockup with the flexibility to evolve into future designs, to validate techniques for maintenance and logistics and verify human task allocations and support trade studies. This work began in early 1985 and ended in August, 1991. The mockups are presently being used at MSFC in Building 4755 as a technology and design testbed, as well as for public display.

Micro Craft also began work on the Process Material Management System (PMMS) under this contract. The PMMS simulator was a sealed enclosure for testing to identify liquids, gaseous, particulate samples, and specimen including, urine, waste water, condensate, hazardous gases, surrogate gases, liquids, and solids.

The Space Station would require many trade studies to validate techniques for maintenance and logistics and verify system task allocations, it was necessary to develop a full scale mockup which would be representative of current Space Station design with the ease of changing those designs as the Space Station design evolved and changed. The tasks defined for Micro Craft were to provide the personnel, services, tools, and materials for the Space Station mockup which would consist of four modules, nodes, interior components, and part task mockups of MSFC responsible engineering systems. This included the Engineering Control and Life Support Systems (ECLSS) testbed. For the initial study, the mockups were low fidelity, soft mockups of graphics art bottle and other low cost materials, which evolved into higher fidelity mockups as the R&D design evolved, by modifying or rebuilding, an important cost saving factor in the design process.

Micro Craft, Inc. designed, fabricated, and maintained the full size mockup shells and support stands. The shells consisted of cylinders, end cones, rings, longerons, docking ports, crew airlocks, and windows. The ECLSS required a heavier cylinder to support the ECLSS systems test program. Details of this activity will be covered in the body of the report.

Support stands were designed and built for each module sufficient to move and rotate each module. Secondary structures such as floors, ceilings, bulkheads, standoffs, racks, etc. were developed and built. Systems were configured for communication and data handling, electrical power systems, experiment support elements and logistics/ maintenance concepts for payload, a water reclamation facility, PMMS test facility, thermal control system and PMMS glove box tests. Interface mockups were also developed for study, such as the Orbiter Maneuvering Vehicle (OMV). Micro Craft provided on-site personnel for these activities at the fabrication shop in Building 4755. This capability provided quick response to design changes or experiments with the present design. On-site personnel were also provided to support the ECLSS/PMMS test program.

During the course of this contract, Micro Craft supported all activities concerning the Space Station Freedom development, Public Affairs requirements, and important NASA functions in the 1-G testbed and the ECLSS/ PMMS testbed.

THE BEGINNING

The definition of the Space Station was very sparse at the beginning of the contract. The object was to support the early designs and to use items that were on hand or that could be manufactured using low fidelity materials such as Fome core. Wooden mockups of the cylinders were obtained and placed together to form a Space Station. Micro Craft updated these modules (see Figure 1) with paint, lighting, and new floors. The interiors were outfitted with Fome core racks and interiors of these racks supplied with items, such as microscopes, made from bottles and bottlecaps to simulate lenses. Low fidelity allowed engineers to visualize paper designs and ensure compatibility with other designs. As the R&D process progressed, existing low to medium fidelity mockups were modified or completely rebuilt, an important cost-saving factor in the design process. The experience of Micro Craft personnel in engineering and fabricating models and mockups was especially important to cost containment This experience allowed them to produce innovative solutions to any mockup problems and to advise MSFC personnel on areas in which low fidelity would be adequate to meet the design or human factor requirements.

On-site Micro Craft personnel staffed the fabrication shop to provide quick turn-around as the requirements were quickly changing. All skills were provided for carpentry, graphics art board work, metal work, painting, electrical and air conditioning for these early wooden shells. Micro Craft engineers also assisted MSFC in the design, construction, and operation of a new fabrication shop next to Building 4755 during the contract. Design and computer support were provided.

Many designs were being considered for rack placement, size of racks, standoffs, length and diameter of shells, lighting, work stations, and other designs, some part task mockups were used. A very good example of this work was the "Bologna Slice", a section of the Space Station made to demonstrate the concept of dividing the station into vertical sections simulating floors in an office building, each floor outfitted for various tasks in a Laboratory. Figure 2 shows a section of the Bologna Slice interior. Micro Craft manufactured the slice and outfitted the interior with racks of graphics art board for study.

Various sizes of racks were built and installed in another part task mockup for evaluation and study by R&D engineers at MSFC to determine the size and shape rack that would maximize the usage of the interior dimensions of the shell. Figure 3 is a demonstration of this study. This study was very important in determining rack size. A 74.5" rack and an 80" rack were both fabricated and installed on standoffs. Two shapes of each size rack were built.

A low fidelity mockup of a resupply item was completed. This mockup was the Orbital Maneuvering Vehicle (OMV), which would dock with the Space Station truss assembly with the station Remote Manipulator Arm (RMA), and provide fuel resupply for the station. This also was a very early design, therefore completed with low cost materials to demonstrate a concept. Figure 4 shows this early concept.

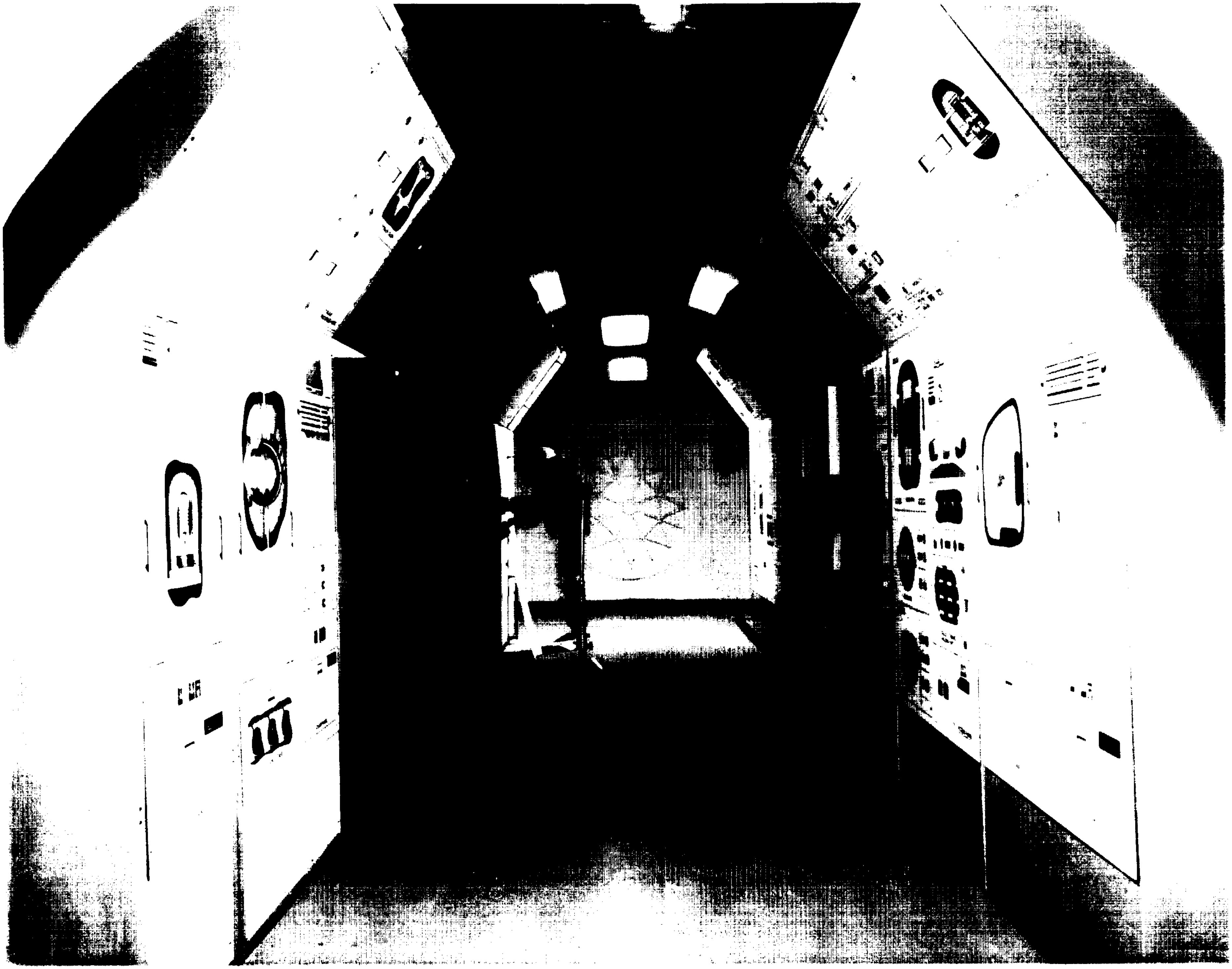

Figure 1 Interior of Early Space Station

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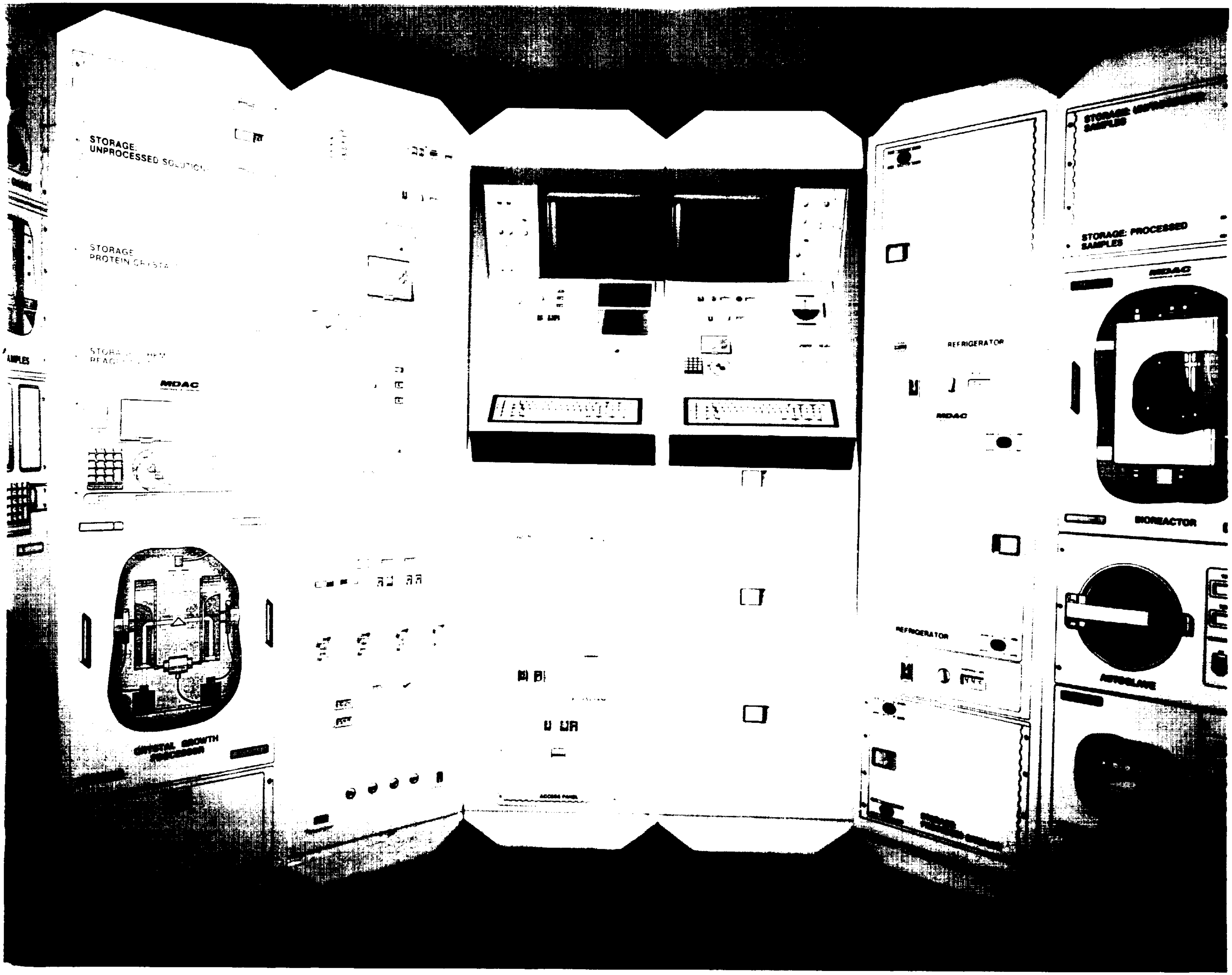

Figure 2 Bologna Slice

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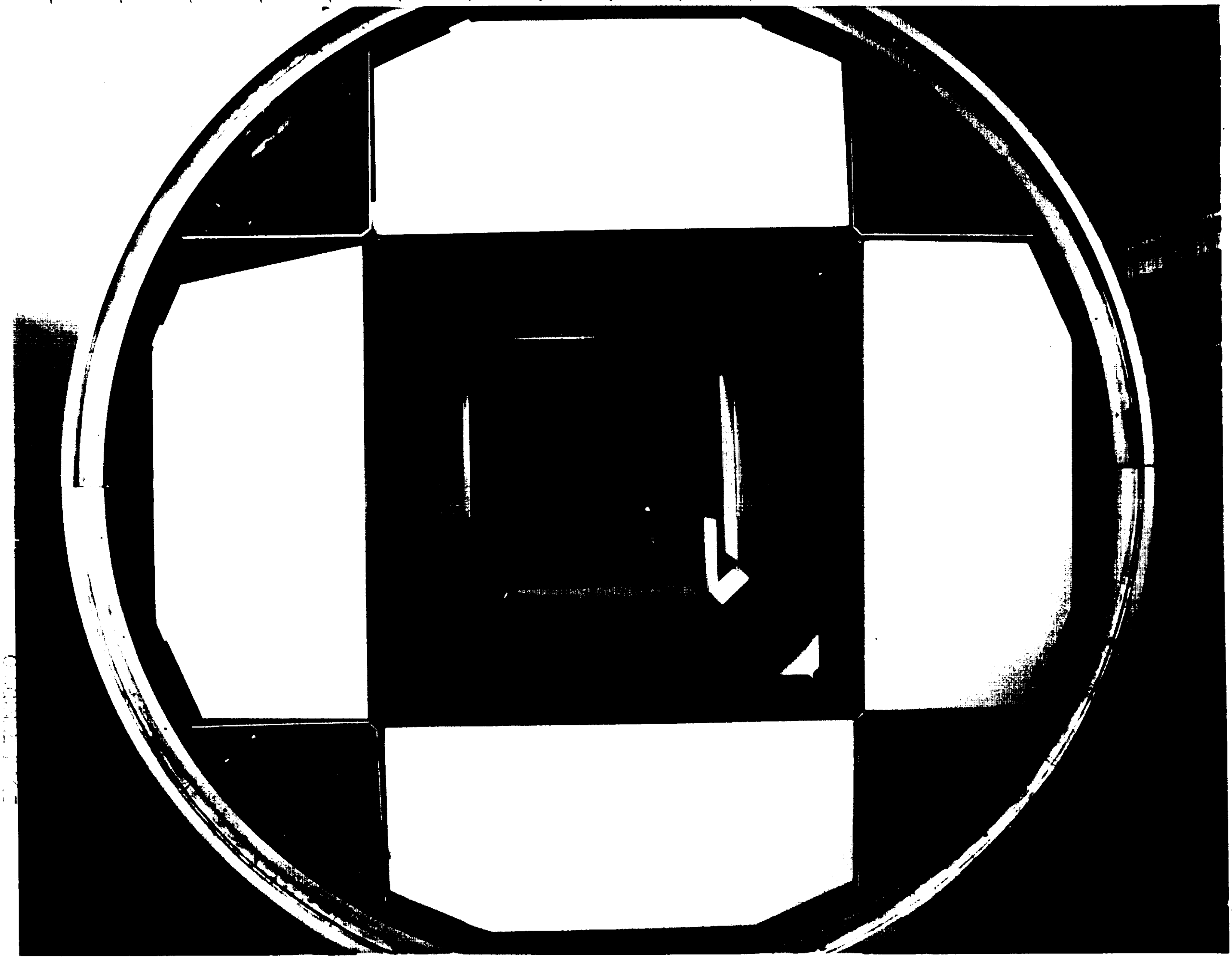

Figure 3 Fome Core Part Task Mockup of Racks

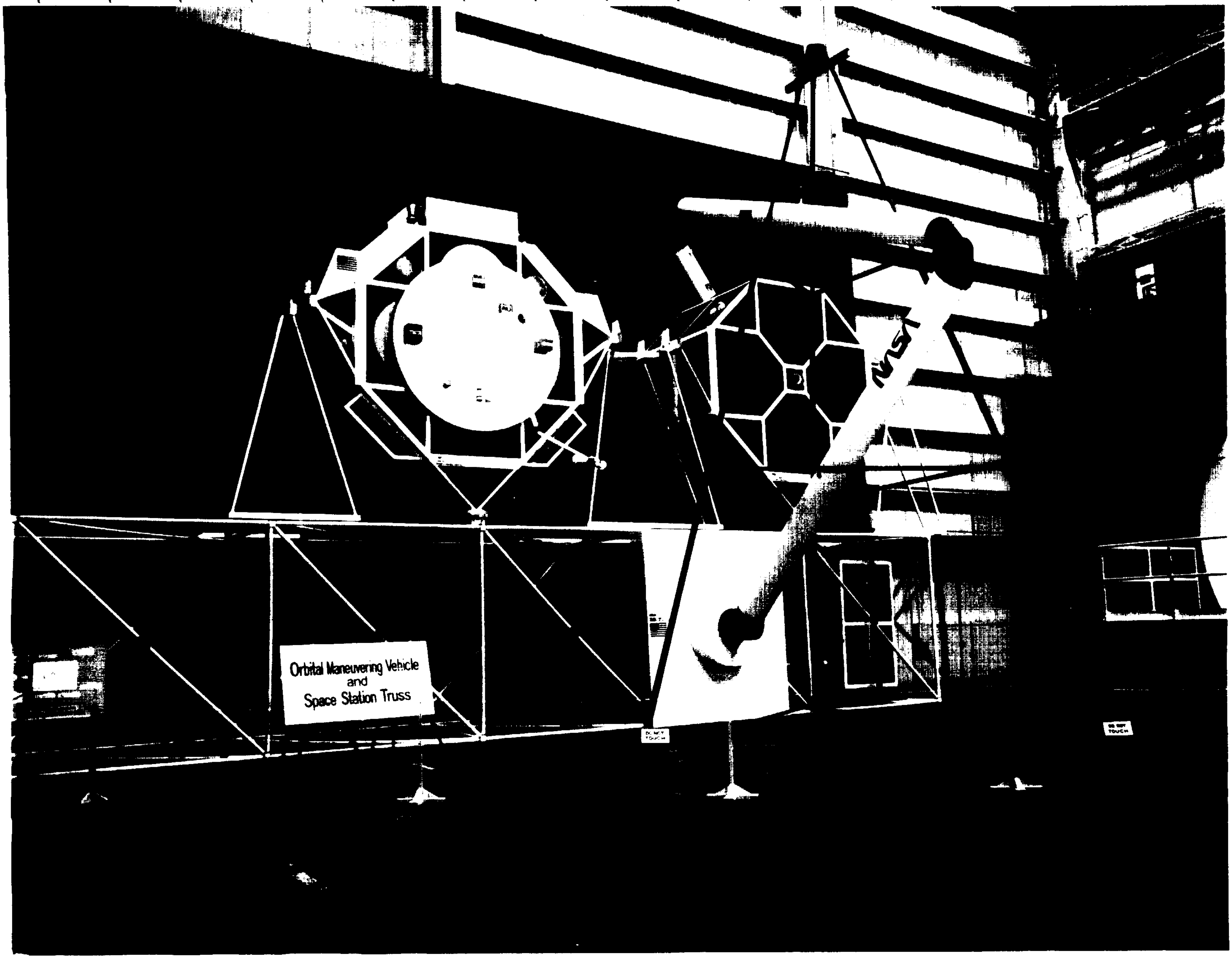

Figure 4 OMV Mockup

ENGINEERING MOCK-UPS

The next step in the engineering design process determined the diameter and length of the Space Station modules. Micro Craft then proceeded to fabricate these shells of aluminum alloy. These modules were manufactured to be flexible, to accommodate design changes. The rings were made in ten foot sections and bolted together. The length of the modules could then be easily changed. The first two modules fabricated were the Habitability and the Laboratory sections. They were later joined by Nodes and a Logistic module. The Jem and ESA were added later to give a full Space Station race track. Figure 5 shows this layout.

End cones were manufactured by on-site technicians and installed. Figure 6 is an example of the manufactured end cone. These end cones consisted of rings, inner and outer, ribs, and aluminum sections. This required metal shearing, rolling rings, bolting sections, and welding. These were then painted and installed.

Micro Craft provided engineering support, fabrication technicians, installation, and materials for the Hab, Lab Nodes, and Logistics modules. One of the innovative designs was for moveable floors in the modules designed to change height as the rack design studies progressed and rack sizes changed. Figure 7 is an interior shot of a module with a variable height floor. This was accomplished using turnbuckles. These floors also had to be designed to take a load of 150 pounds per square foot, since these modules were to be used as engineering design tools as well as for public tours. The floors were subsequently covered with plexiglass to prevent the scratching of the floor racks. The design had evolved into racks on ceiling and floor as well as both sides of the modules. Figure 8 is an example of installation of the racks.

Transporters for each of these modules and Nodes were designed and fabricated by Micro Craft, which could withstand the load of each module, provide the capability to move the modules to new positions, and to roll the modules 360 degrees on the cradle. These stands were manufactured from aluminum I-beams with 8 inch rollers. This design allowed flexibility in studying Space Station configurations, and ease of installation of racks within the modules.

From the previously built and studied part task mockups of rack designs, the size and shapes of the racks were decided. Micro Craft then began to build the racks with an aluminum frame to fit on standoffs in each quarter section of the module. These racks were stationary in the beginning and evolved to removable racks which could be tilted out. Figure 9 shows a tiltable rack in the Space Station Laboratory module.

HABITABILITY MODULE

The Habitability module was the first configuration built since there were several types of racks involved and there was more definition available. Figure 10 is of the Space Station Habitability module layout indicating the various areas and the use of that area. For example, the crew quarters were a different size from the computer work station and stowage racks. The eating area required installation of a table which folded, box like, into the wall rack. Figure 11 shows this area. A health facility, shown in Figure 12, was fabricated with a folding stretcher and the exercise facility had an open front with exercise equipment installed. The Waste Management system included the commode area

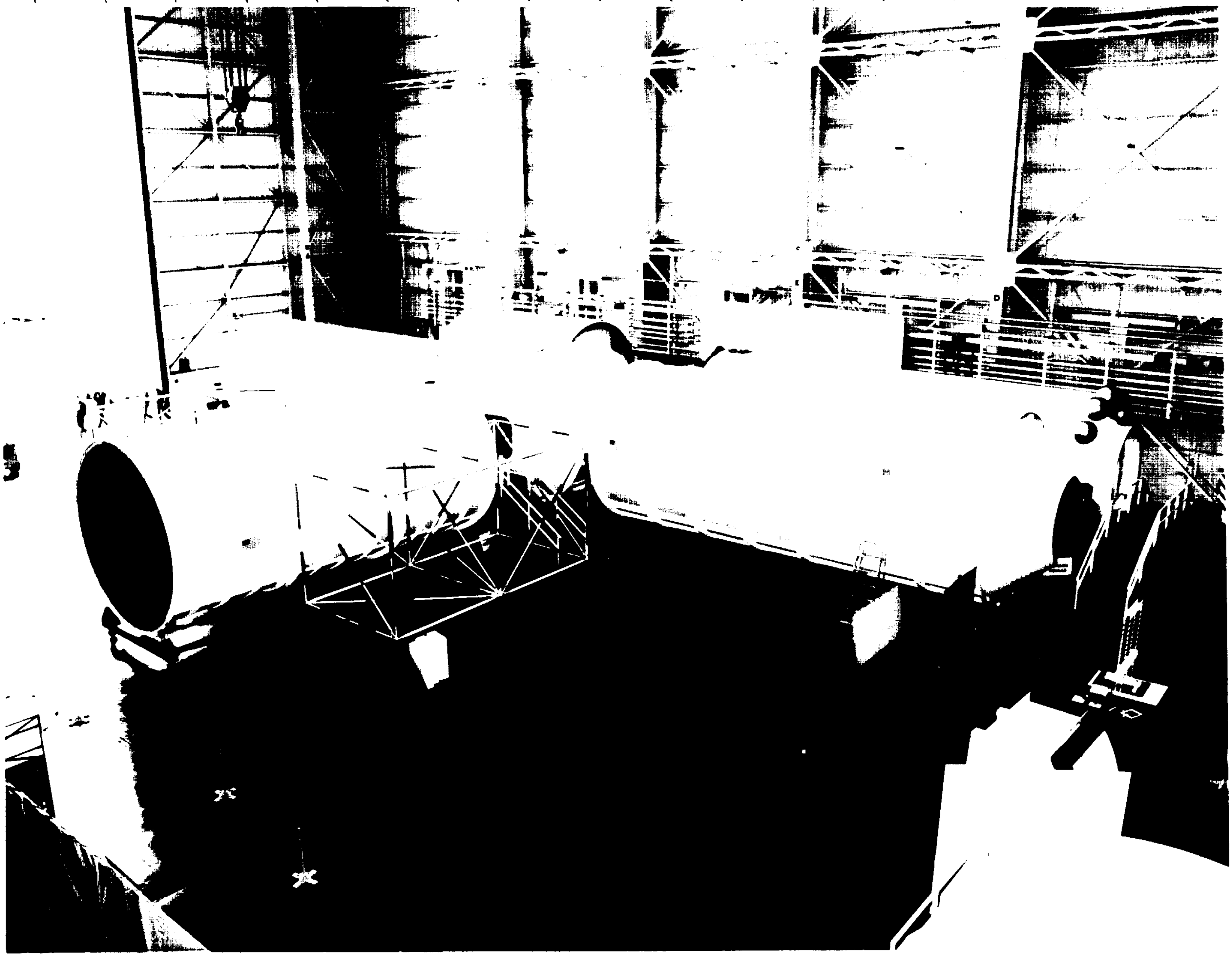

Figure 5 Early Full Racetrack of Space Station

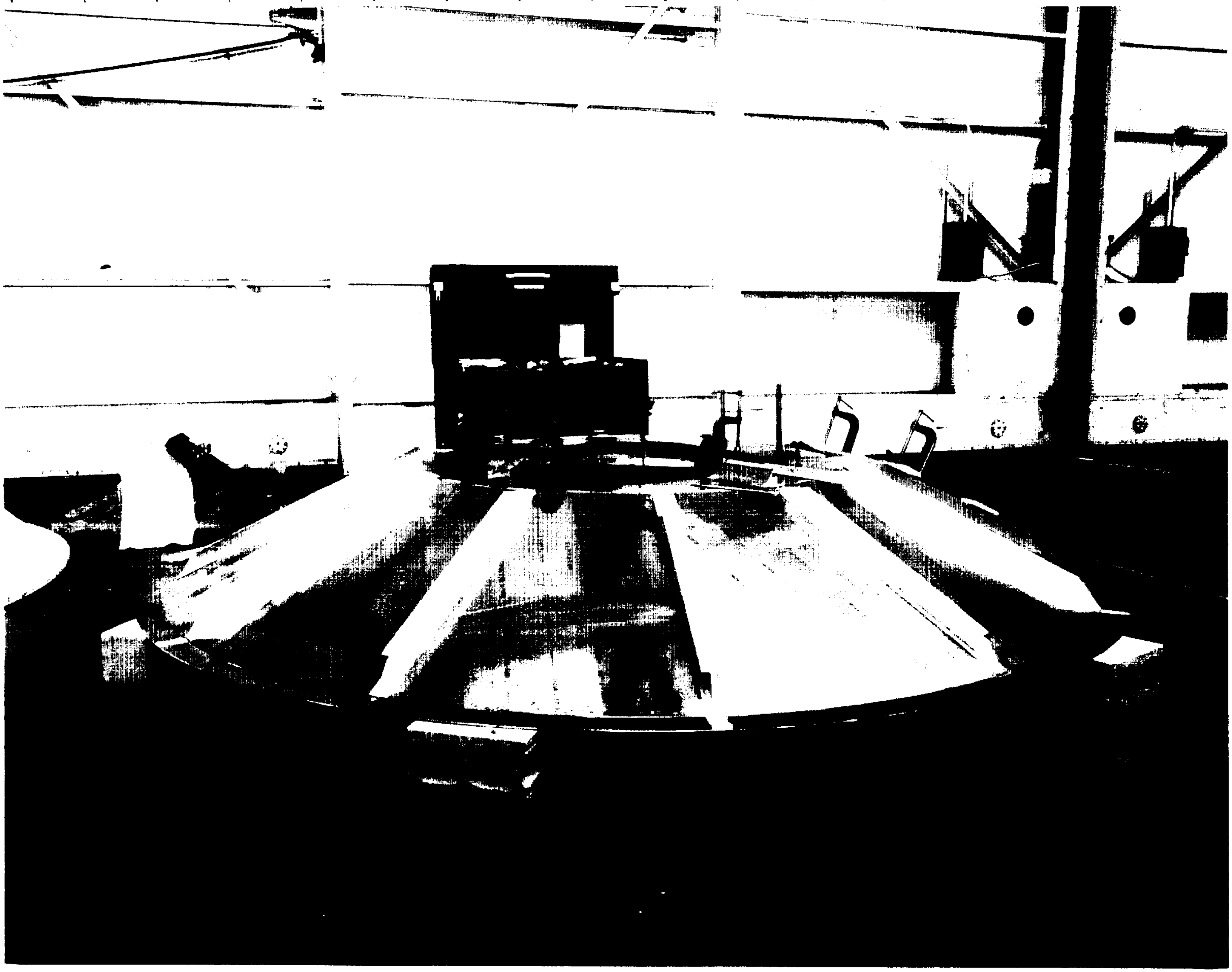

Figure 6 End Cone Manufacture

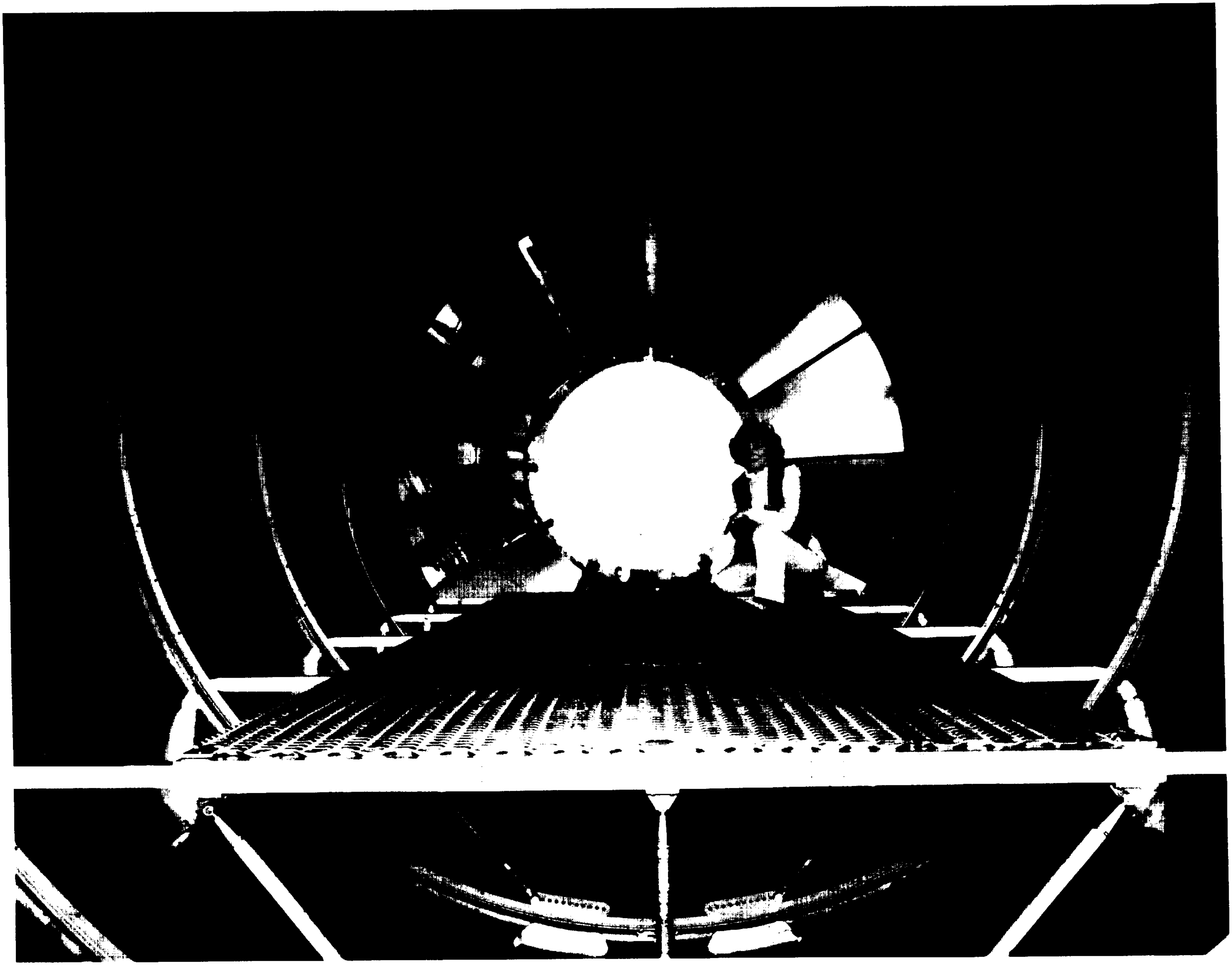

Figure 7 Moveable Floors

Figure 8 Rack Placement

Figure 9 Tilting Rack

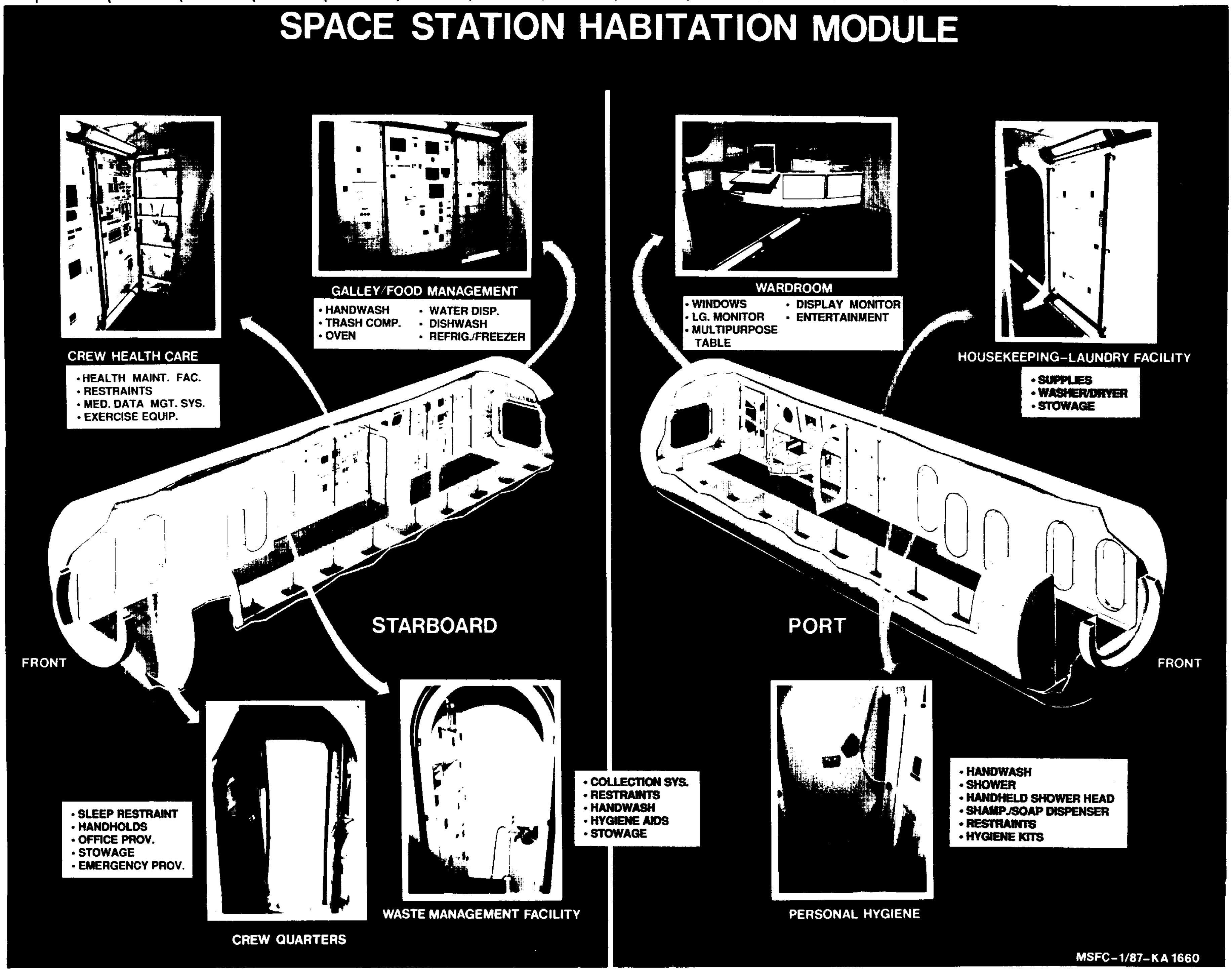

Figure 10 Hab Module (MSFC 9/87-KA-1660)

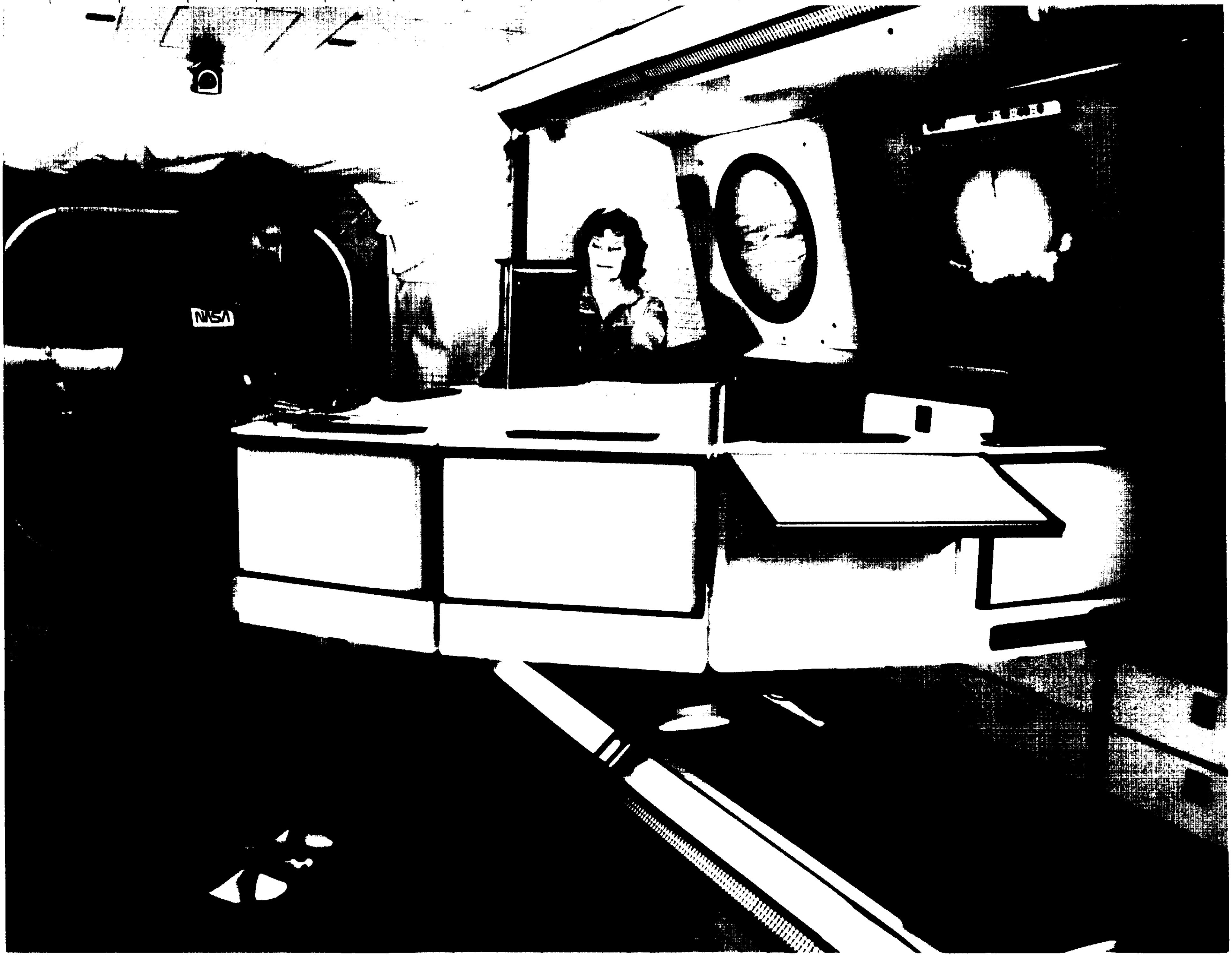

Figure 11 Table Galley Ward Room

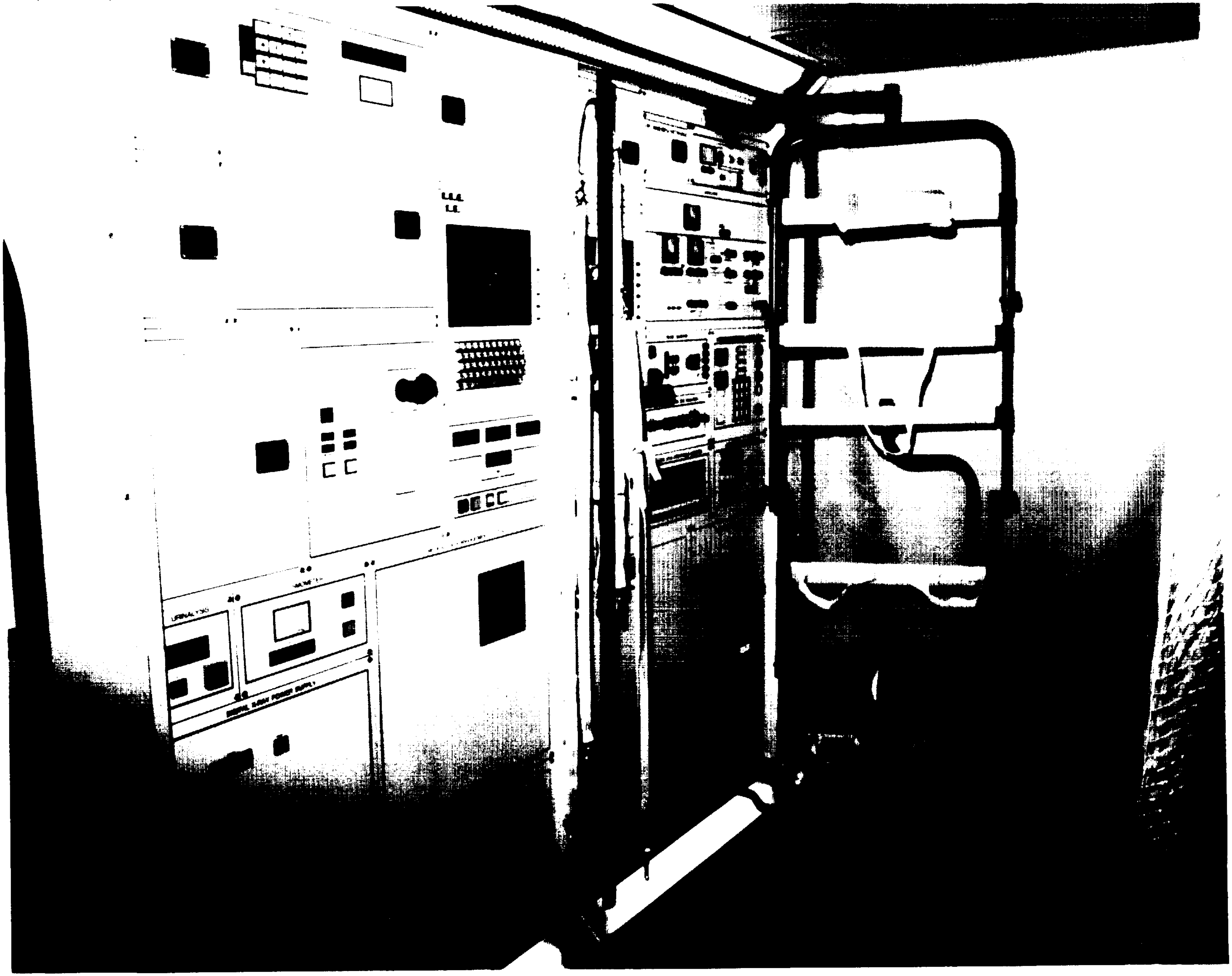

Figure 12 Health Facility

and shower area. Micro Craft adapted and installed the shower in accordance with Johnson Spacecraft Center (JSC) design. A commode was also fabricated to meet the current design. Figure 13 shows the commode and shower racks. The other racks were built with aluminum fronts with latches installed and lettering to indicate the purpose of the rack. Racks were fabricated to be interchanged with one another for flexibility as the design matured.

The Crew Quarters were fabricated and installed as shown in Figure 14. The interior of the Crew Quarters included simulated video monitors, computer with keyboard, caution and warning equipment, an audio/video communication system access. A sleeping bag was installed and a pull out desk provided. Trash stowage and stowage for personal items were fabricated and installed. A sliding door was installed for privacy. Workable racks were fabricated for each side wall and simulated aluminum fronts were made and installed in the ceiling and the floor.

Several racks were provided for Space Station stowage. Micro Craft technicians provided the detailing and decals to show stowage drawers plus identification to aid in the study of stowage concepts. A soft stowage pack was built and installed on the front of a stowage rack to study additional stowage requirement possibilities. A standoff stowage concept was also provided.

A computer work station, shown in Figure 15, was provided in the Hab module. This rack consisted of a rotating upper half with the lower half stationary. Micro Craft provided technical assistance in design and fabricated the rack. Knobs and switches were installed along with simulated flat panel TVs.

Simulated windows were built and installed in the appropriate locations to aid in window placement studies. These were located in the Wardroom and exercise areas. The Galley/Wardroom consisted of the table described above with stowage walls, rack installed for refrigerator freezer, trash compactor, washer/dryer for laundry, dishwasher, stowage and handwasher. Lighting was fabricated and installed in the standoff areas as in other parts of the Hab module. Functional camera equipment was installed in the Galley end of the module.

Micro Craft provided skilled technicians and engineers for this task. Carpenters, metal workers, welders, painters, electrical and air conditioning specialists were provided as well as computer personnel. Air conditioning ducts were designed and installed in the module by Micro Craft technicians for comfort within the module of design engineers working there.

LABORATORY MODEL

When the Habitability module was completed, the team then completed the Laboratory module at a medium - high fidelity phase. Both modules are cylindrical and measure approximately 42 feet long and 14 feet in diameter. The U.S. Lab module is shown in Figure 16 with the various elements allocated to the Laboratory.

The Laboratory module contains a series of experiment racks measuring approximately 21" x 74.5" for a single rack and 42" x 74.5" for a double rack. Non-experiment racks, such as work stations (maintenance, element control, etc) and systems racks (emergency, shower, ECLSS processing equipment, etc.) were also included and measure approximately 42" x 80". Figure 17 is an interior shot of the Laboratory module with different types of racks.

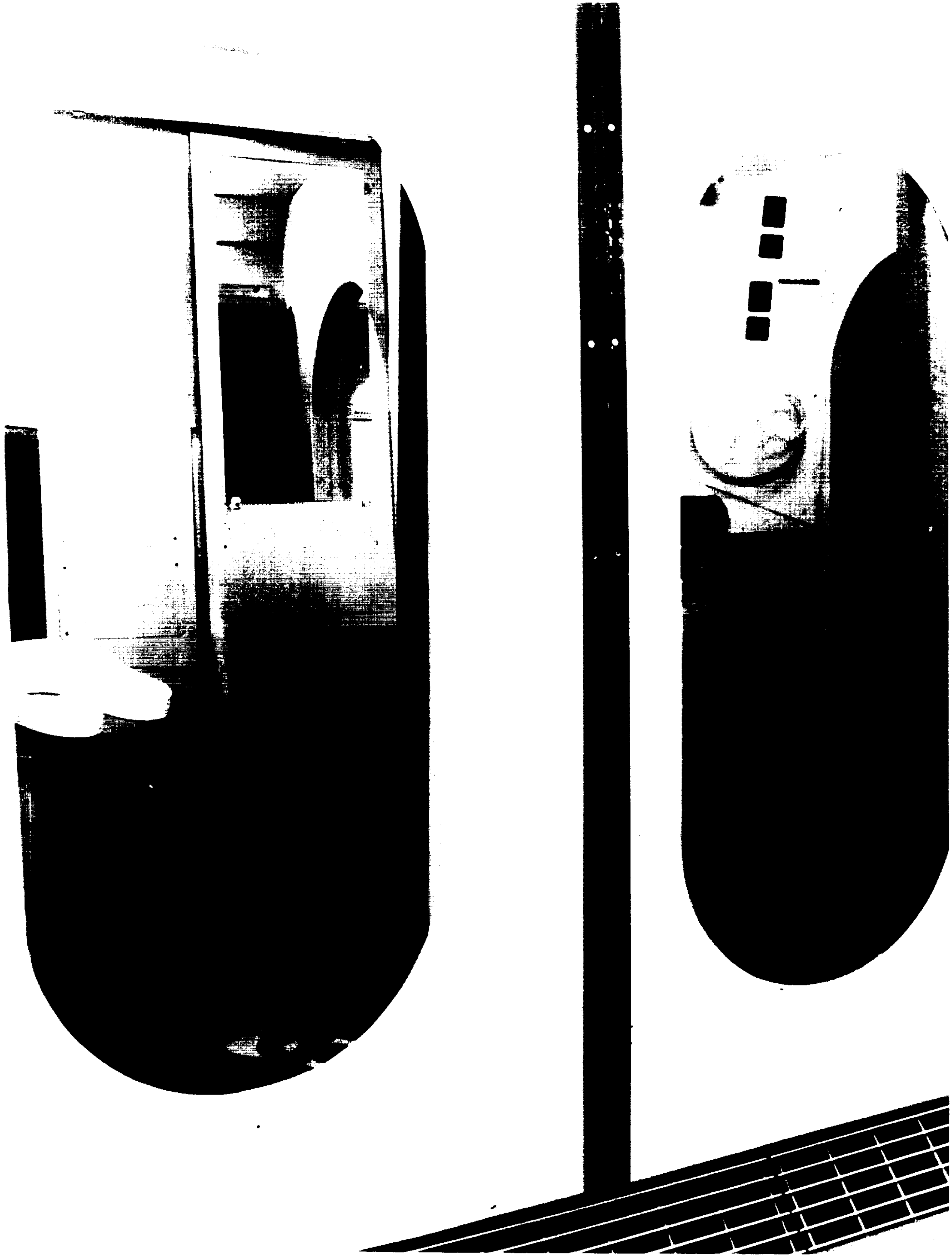

Figure 13 Hygiene Area Commode and Shower

Figure 14 Crew Quarters

Figure 15 Work Station

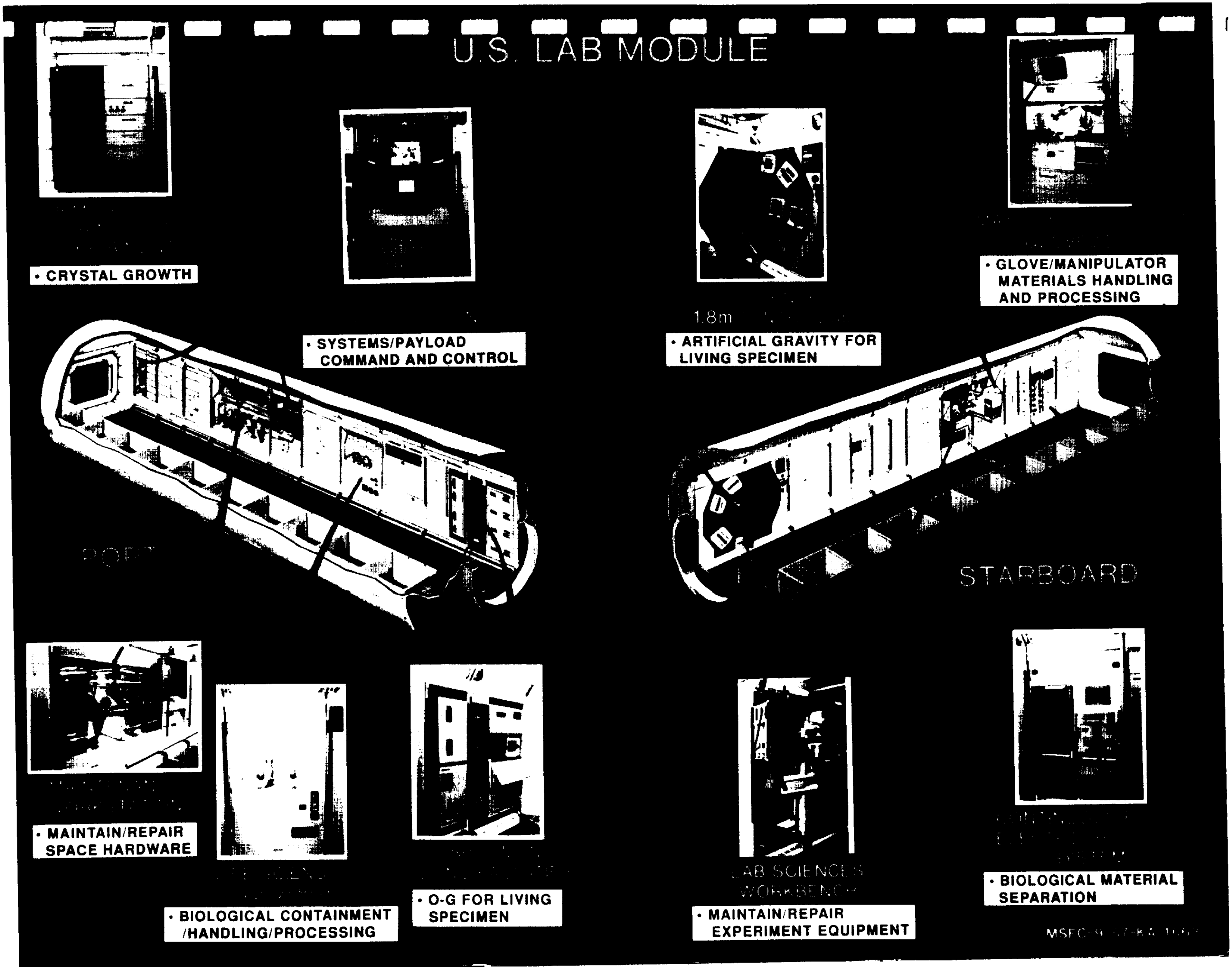

Figure 16 Lab Module (MSFC 9/87-KA-1668)

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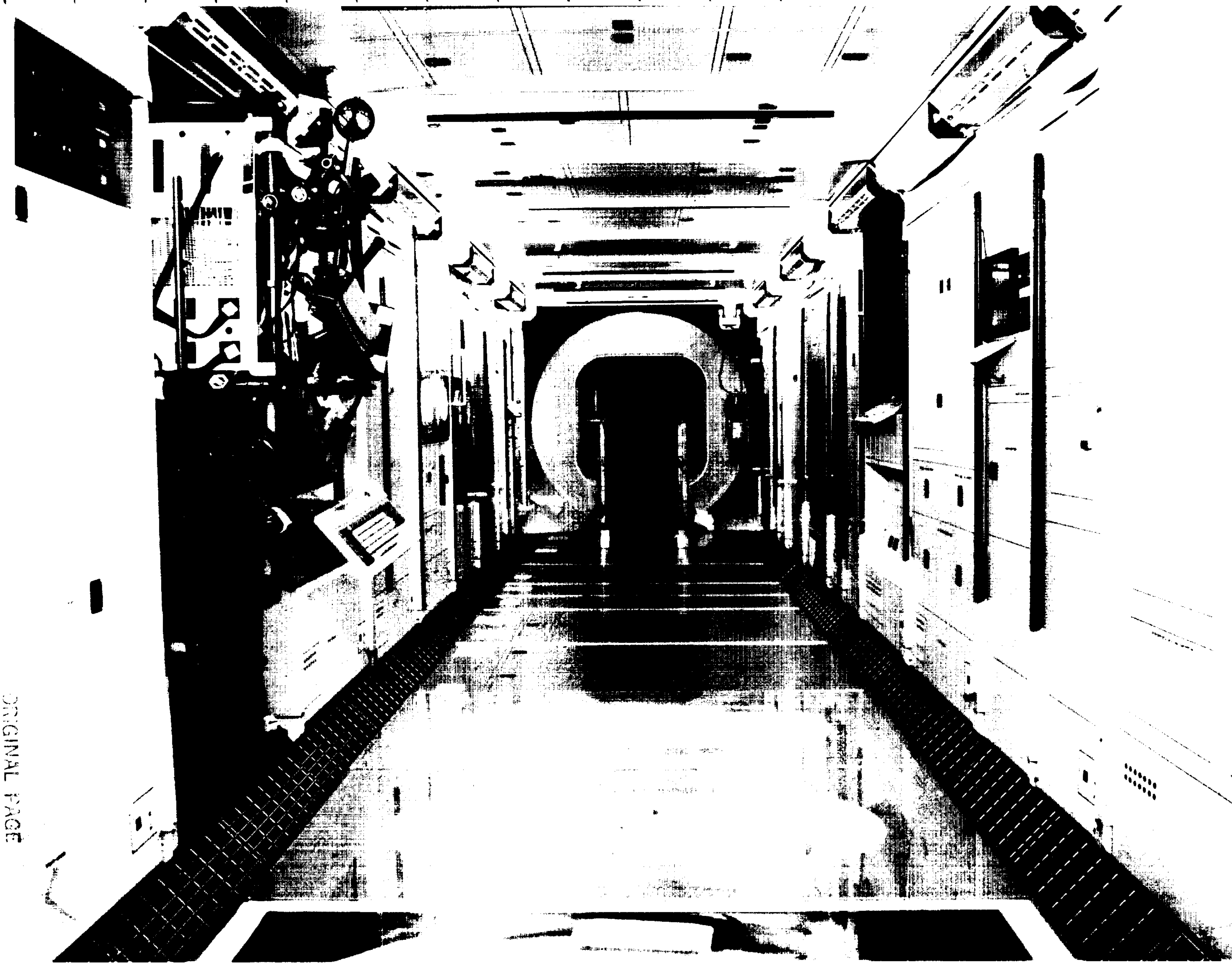

Figure 17 Interior of Lab

Triangular standoffs separate the racks. This was a full scale engineering mockup which included experimental payloads and workstations for laboratory experiments. Updated racks were fabricated for this module that were fully tiltable on aluminum standoffs. New lighting boxes were designed and built into the standoffs (this design will be discussed later in the report.) Within this module, several types of racks were designed and built to accommodate various scientific payloads. Although the racks were of a common basic size, the interiors could be different. Micro Craft technicians worked with the Ames Research Center design for the Life Science Glovebox, Equipment Washer, Biospeciman Holding Facilities (rodent and plant), and the Life Science 1.8 meter Centrifuge. The designs were manufactured exactly as those presented by Ames and were installed within the Laboratory module as specified by the then current design.

The mockups were built of aluminum and painted to match the Lockheed and Boeing mockups. The rack dimensions were according to specifications. All equipment and special payloads had to fit within the reference standard rack. The mockups were now operable, with the exception of the centrifuge obtained from Ames Research Center, with upkeep, installation, and operation by Micro Craft technicians who maintained and operated the 1.8 meter centrifuge, a totally computer automated machine, that indexed, selected, and extracted animal habitats as rotation continued. Also, one area of the rodent habitat opened to show how an animal holding box could fit within the rack. Switches, latches, and cabinet hardware were installed on the rack fronts.

The Life Science Glove Box mockup included two aluminum racks with a pass through for modular habitats, tools, and materials. Figure 18 is a drawing of the Life Science Glovebox Rack. There were two glove ports in a .12 stock plexiglass front, an air supply area, lighting, and subsystem control panels. The rack was fabricated from 6061-T6 aluminum alloy .12 stock, and 5052-T6 alluminum alloy .09 stock. The gloves were shoulder length latex. Metal hinges were used, latches were functional or mockup designs. Control panels included toggle switches (CRES), rocker switches, multiple position switches, lights and bezels. Representative access doors and panels were shown on tthe flat rack face for the Equipment Washer. Figure 19 is a drawing of the Equipment Washer Rack.

Within the Lab module, Micro Craft also fabricated a simulated Materials Processing Glovebox, Element Control Workstation, Chemical Vapor Transport Experiment, Furnace Facility, Maintenance Workstation and Continuous Flow Electrphoresis System constructed simnilar to the Life Science equipment. Maintenance and upgrading were continuously provided on these systems. Air conditioning ducts were designed to properly exit from the light boxes per the current design. This allowed engineers and man/system personnel to study the air flow at the work racks, as well as lighting needs.

LIGHTING

Light boxes were built to specifications of the lighting engineers, with lights installed, air flow vents, and communication (audio and video) provided for. A subcontract was let to Gobble Hays Partners with the design engineer being Ray Mullican (he was a consultant contracted to study the Space Station lighting).

The design problem was to develop a concept for a lighting system that creates a comfortable and functional environment, a lighting system which is relegated to an

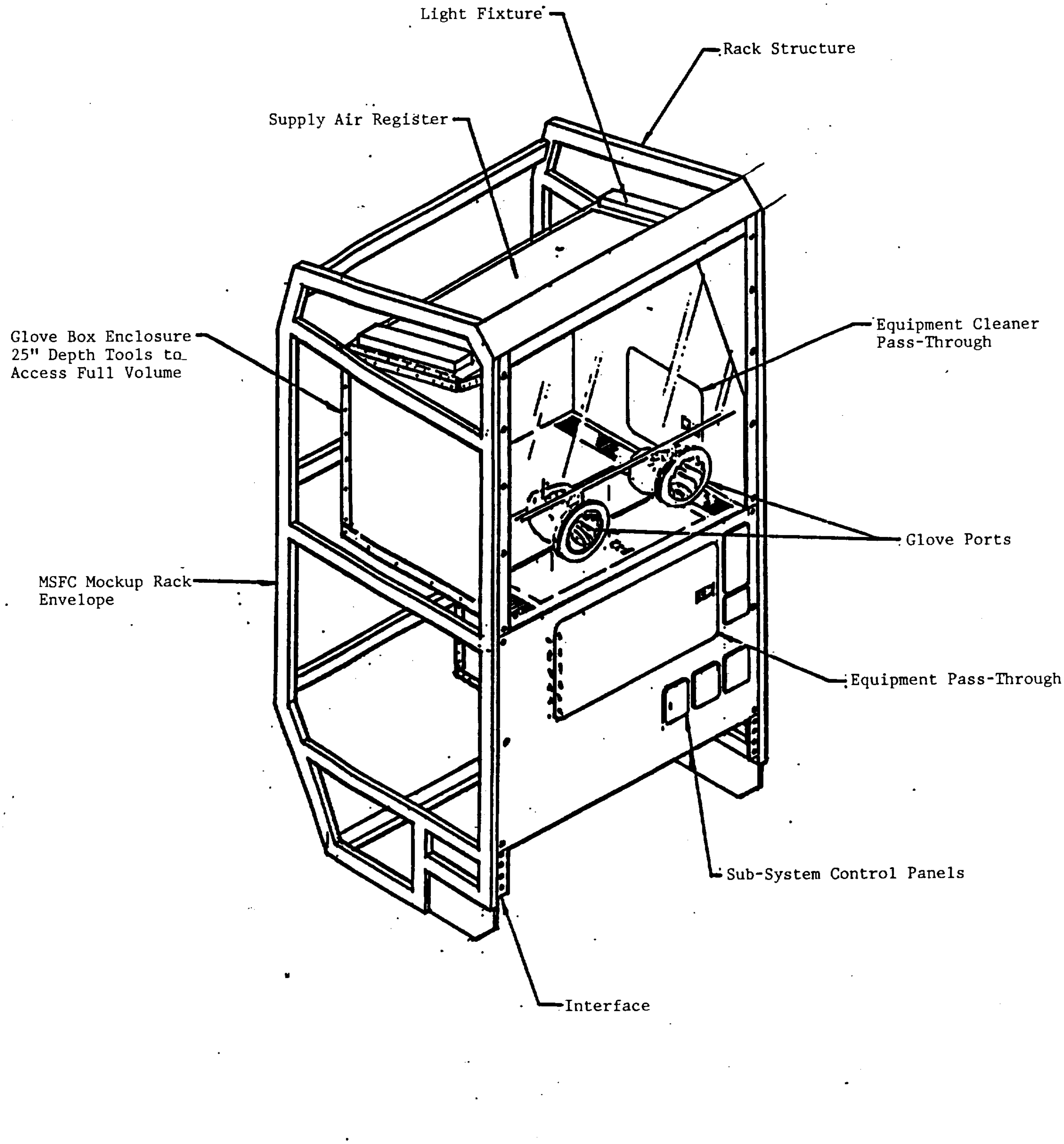

Figure 18 Glove Box Drawing

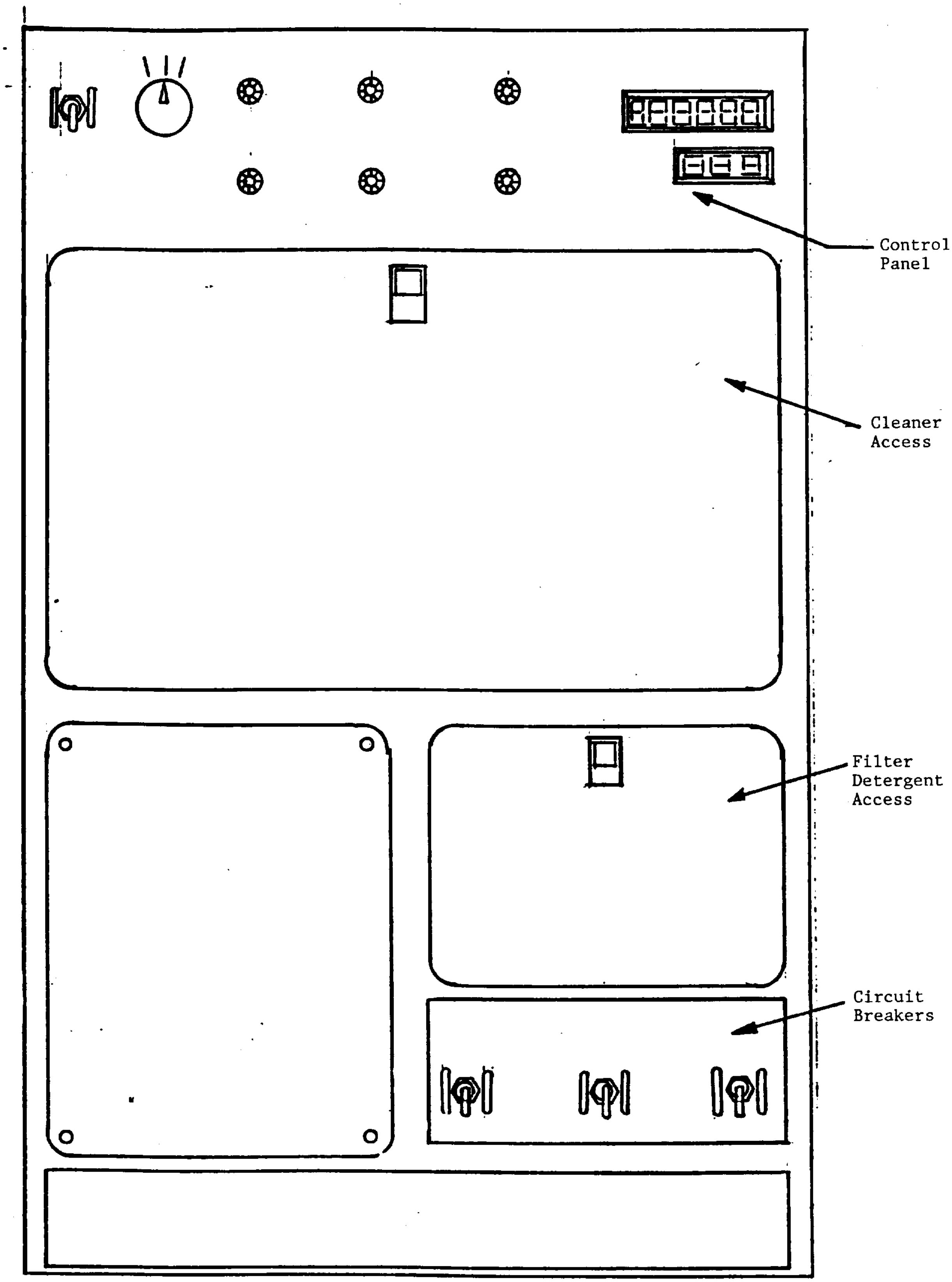

Figure 19 Washer Drawing

extremely small area which must be able to withstand vibrations of a Space vehicle lift-off and yet operate in the zero gravity of low earth orbit.

One of the first tasks was the mockup of the Habitation module in the low-medium fidelity phase. This was analogous to stage set lighting, making the model appear more realistic. Next came the design for functional lighting, developing the specialized applications needed in flight. The first "light box" concept, an integral part of the standoff was packaged to contain air diffusers, returns, two light sources and reflectors, individual switches for lighting, data connection points, audio and video plugs, and duplex outlets.

One of the major design problems was integrating all these lighting, video, and audio systems into a very small space, roughly a 4" x 4" x 24" section. In addition to the constraints of physical size, light box movement had to be addressed. The light source, which had to be in front of the rack to light the rack face, interfered with the removal and insertion of the racks. The solution was to slide the light box into the standoff, exchange the racks, and then reposition the light box.

The primary lighting concept is one common to many earth-bound work environments: task/ambient lighting. Ambient lighting of a 15 - 20 fc. range provides the means by which one maintains orientation in a given space. To accomplish this, only the rack faces are illuminated; the rack surfaces are utilized as secondary reflectors to provide light in the center zone. Since the light source is so close to the wall, the raking angle highlights the relief of the rack surfaces, providing a good modeling of switches and controls for easy visual identification.

Another major concern has been to balance brightness ratios in order to minimize display screen reflections and the potential for fatiguing extreme visual adaptations. To this end, a fairly uniform wall luminance has been accomplished by achieving a luminance ratio of 5:1. Also, the ratio of the fixture luminance to the adjacent backgrounds has been minimized.

Direct glare is a problem compounded by zero gravity, in space one's feet are not necessarily confined to the floor, thus the astronauts are apt to be looking from unexpected orientations. Direct glare was minimized by providing visual shielding of the lamp. This was accomplished by placing the lamp inside the light box so as to shield direct viewing and augumented with a secondary system of 1/8" internal metal louvers to provide additional visual cut-off.

In addressing the color temperature of the light source, the ambient levels indicate a color temperature preference of 2800 - 3600 K.

The color rendering capability of the source was a significant factor. The long-term habitation of this enclosed environment makes it a major phychological concern that colors be rendered accurately, particularly skin tones and foods. The 3100 K Sylvania Octron with a CRI of 75 was used to resolve both color temperature and color rendering design constraints.

Because many elements (power, air, audis, videos, etc.) were packaged within such a small space, several variables in the reflector design were pushed to extreme limits. The light box, being located adjacent to a rack face, created a hot spot at the source. To address this problem, where possible, the lamp was recessed behind the rack face and modified paracyl reflectors were designed with both specular and diffused components.

Another concern was the size of the lamp in relation to the size of the reflector.

Most reflector design is predicated on the assumption that the light source is so small, relative to the reflector size, that it may be considered as a true point source. In this case, the size of the lamp relative to the reflector is large. Even with the 1" diameter Octron lamp, current calculation procedures were not appropriate, thus prompting the use of traditional methods of reflector design. Additionally, the size of the reflector makes it difficult to provide the necessary optical control and intensity necessary to uniformly light the rack face.

A prototype light box was constructed to evaluate success in overcoming these design problems. After testing and modifying the prototype, a small assembly line was set up with Micro Craft technicians to produce the forty-four required light boxes. This usage is shown in Figure 20 and 21.

Later studies included developing the ambient lighting and addressing several associated problems. Additional work is required to reduce fixture luminance. Additional methods to study are for optical control and visual shielding, with possible use of holographic films and lenses. Development of light zones within the various modules is desirable, as is the addition of dimming capabilities. Task lighting for indivual work stations and racks was not addressed. The potential for use of fiberoptics is under consideration. Another problem requiring investigation is the concern of uncontrolled sunlight through viewpoints.

As we move beyond stage set solutions, fixtures and light sources must be "space qualified", to withstand the vibrations produced in leaving the earth's atmosphere. The light boxes must also be durable, for the simple reason that equipment and the movement of the crew as they float about the module increases the potential for breakage.

Much of the work in lighting design has been concerned with the psychological problems of living in totally artificial environment for as long as 120 days. Research on habitation in space for long durations has shown that humans get disoriented if they have no sense of "up" and "down". The use of coloration and a traditional differentiation in surface reflectances are keys to establishing a "local up".

Utilizing typical ceiling, wall and floor reflectances of 80 - 50 - 20% enables the crew to perceive up and down, and is a very effective tool in minimizing disorientation and space sickness. This is evident when one opens the door on the module "floor" to the bathroom area, and perceives that the toilet is built on its side. However, when the door is closed the crew member is re-oriented to "up" and "down" in that particular space.

The mockup program provides the unique opportunity to experiment and redesign. Rarely does an architect or engineer have the luxury of a second chance of saying "This doesn't work, so let's try something else", but through the mockup process, improvements are made, mistakes are caught and design refined.

The ensuing design developed from these studies was subsequently built and installed by Micro Craft technicians in the Laboratory module. Figure 22 is the interior of the Lab module with the new light boxes installed on the floor and ceiling.

CUPOLA

The design of the Space Station called for a cupola on the top of one Node, shown in Figure 23, and the bottom of another Node. For MSFC engineers to study the feasibility of this design, Micro Craft technicians fabricated a cupola to exact specifications and installed it in the Node. Within this cupola was a two- man

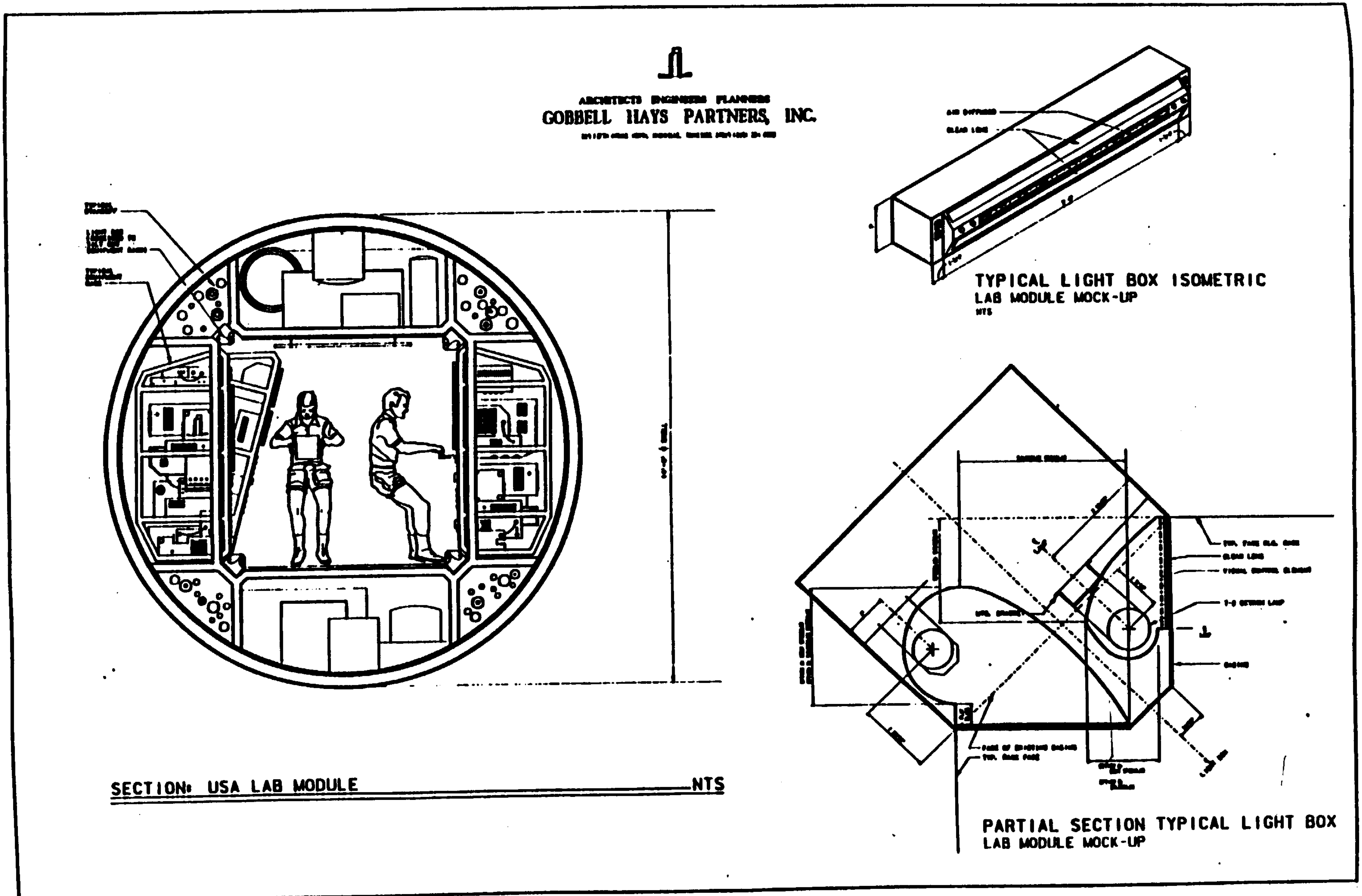

Figure 20 Drawing of Light Boxes

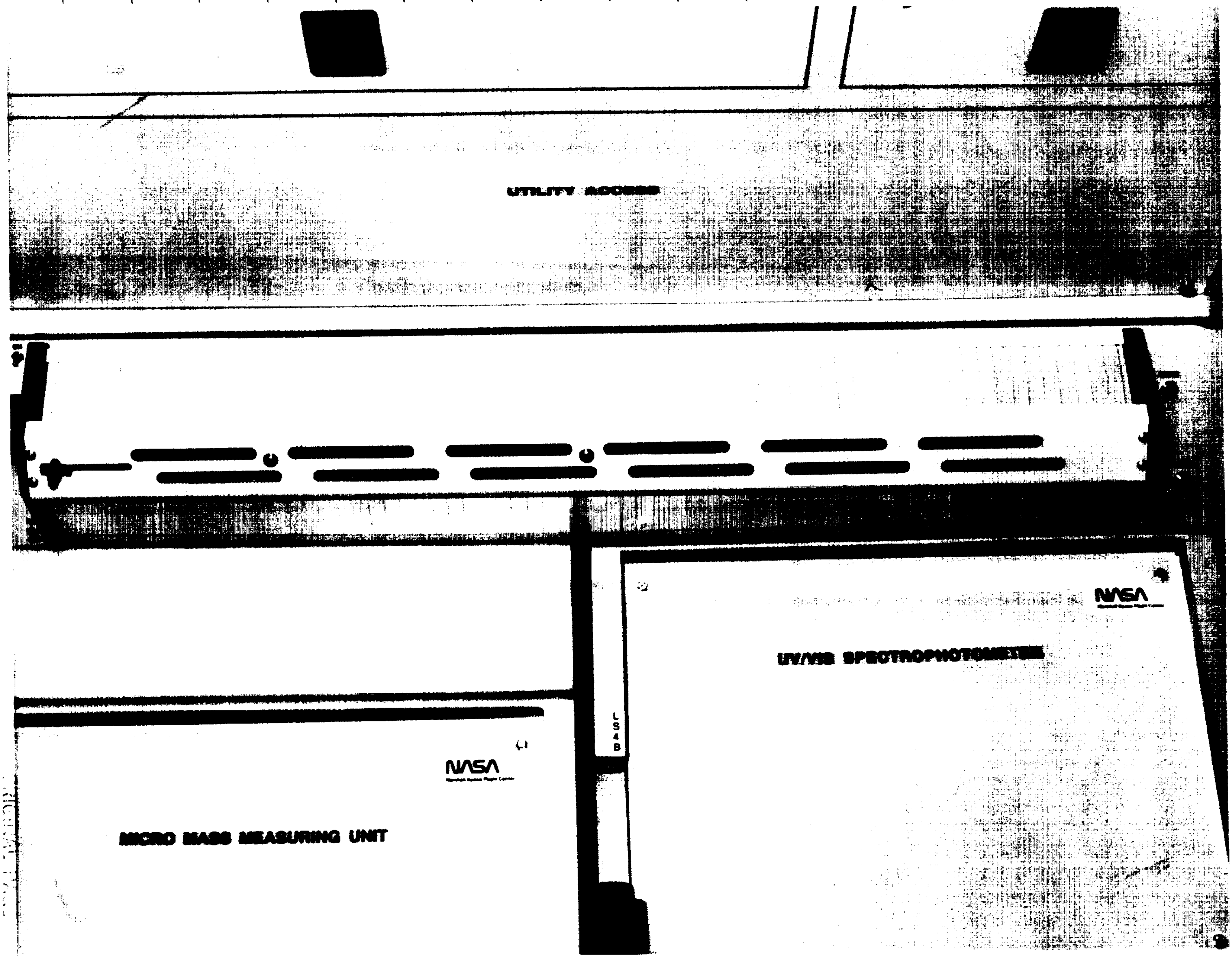

Figure 21 Light Box

Figure 22 Interior of Lab with Lights

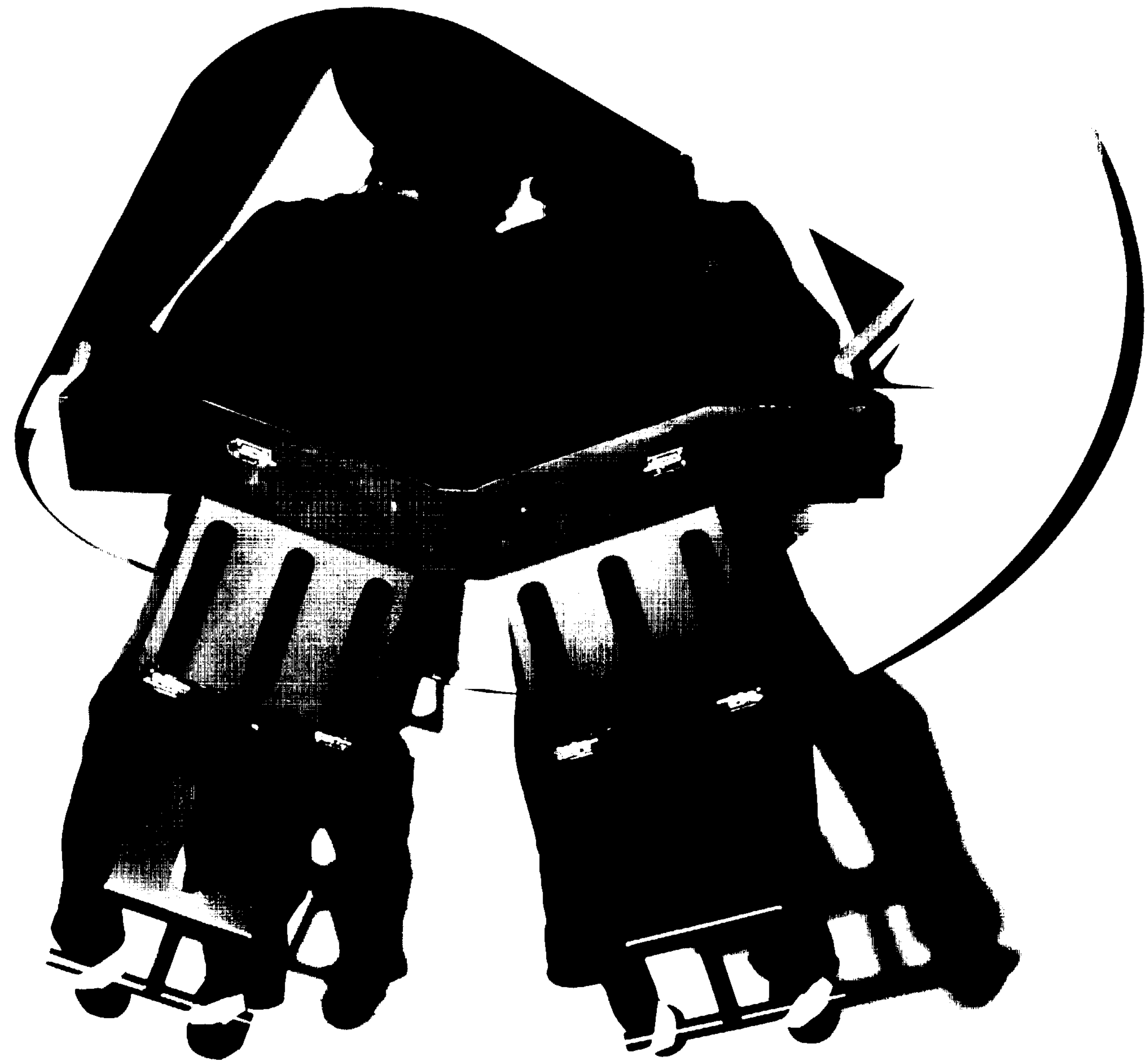

Figure 23 Cupola with Work Station

workstation which was fabricated using a lap top computer and a restraint system of aluminum for two people as shown in Figure 23. Micro Craft assisted with the engineering, fabricated, installed, and maintained this assembly.

A recent example of the utility and cost effectiveness of the Space Station mockup was an experiment to determine if a cupola was a necessary component of the station. Although it would require a mission to transport and at least two EVA's to install, a cupola appeared to be the best method for allowing station occupants to view Shuttle docking and effectively operate the station's remote manipulator arm. To determine if strategically placed portholes could be substituted for the cupola, openings were cut in the mockup and a module was transported across the mockup by Micro Craft personnel operating the crane. The experiment allowed designers to locate "blind spots" and provide an overall evaluation of the competing designs.

LOGISTICS MODULE

The Logistics module was fabricated as described for the Habitability and Laboratory modules. The length of the Logistics module was different, however, It was - 21feet long. The diameter was the same. Rack frames were built for this module with flat fronts. Drawers were installed in the composite rack. Standoffs were built undrer only three racks, next to the 50" hatch.

The end cone at the end of the Logistics module not attached to the station was manufactured to accept a larger hatch to accommodate ground loading.

NODES

Four Nodes were fabricated the same diameter as the aluminum modules for the station, Early studies included various configurations of Nodes made from low fidelity materials. The chosen configuration was made the same diameter but of a shorter length than the modules. Cylinders and end cones were combined to form the Nodes. Four docking ports were installed in each Node.

One study performed in the Nodes included the mockup of wiring and plumbing for the station. Rope and PVC pipe were used in this simulation. Engineers studied these layouts and made revisions to these functions. Micro Craft laid out and installed these configurations.

Outfitting of one end cone was done to show routing of wiring and plumbing into the modules through the hatch. Figure 24 is an example of the use of low fidelity materials to demonstrate this concept.

The cupola was installed in one Node as described previously. A platform was designed and installed in the Node to reach the cupola for viewing studies.

Micro Craft designed, manufactured, and installed walkways and handrails through the Nodes for ease of moving through the station. The Nodes were connected to the Hab, Lab, Jem (Japanese Experiment Module), ESA (European Space Agency), and the Logistics modules to form the Space Station. Figure 25 is the full layout of the Space Station Freedom showing how the Nodes connected these modules to form the configuration.

HAND RAILS

Figure 24 Node Interior with Wiring Mockup

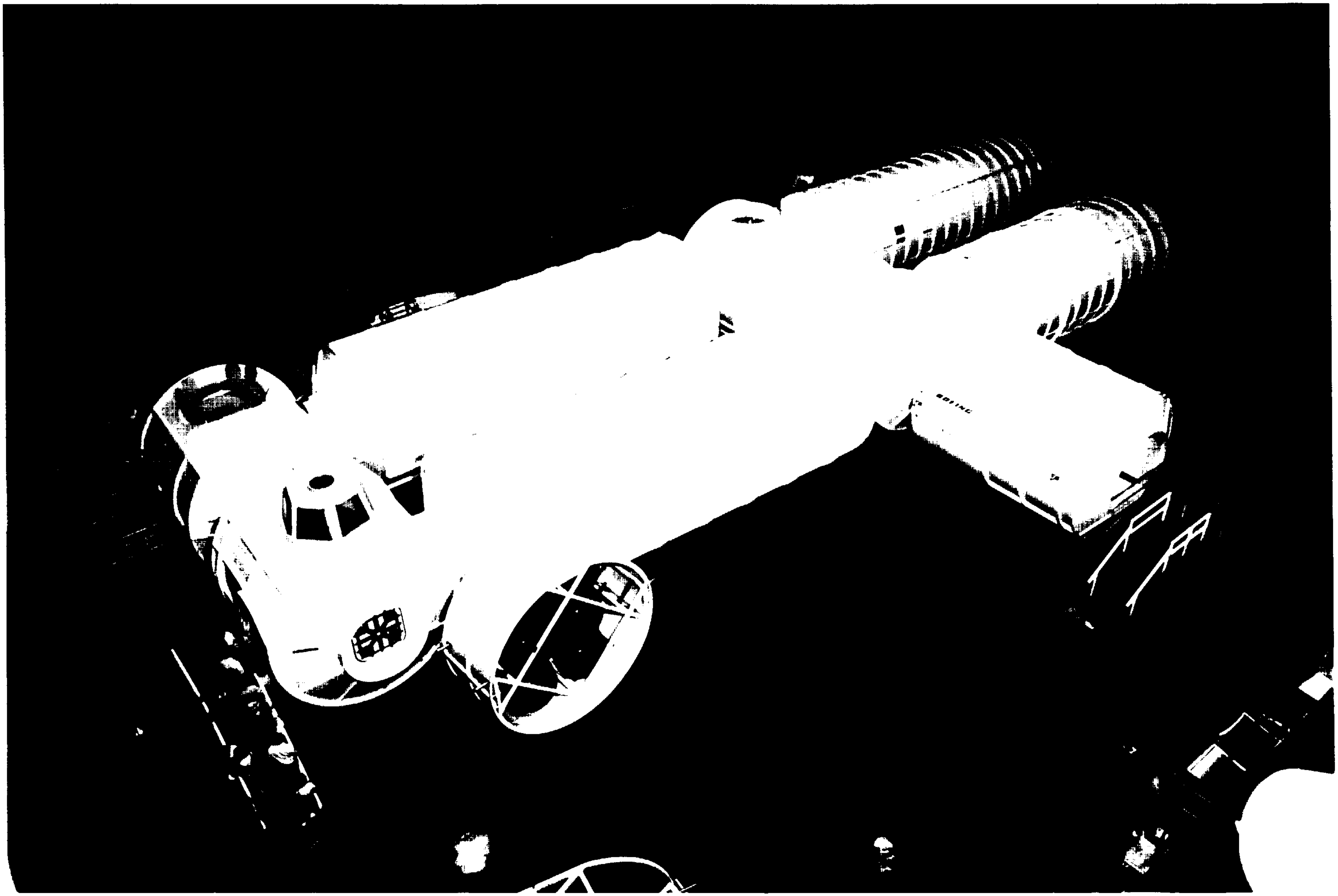

Figure 25 Full Space Station Exterior

Hand rails were needed throughout the staion for Astronaut maneuverability. The first hand rails were similar to the ones used on the Shuttle. Micro Craft provided engineering and technician experience to NASA engineers for the design of a different hand rail. This design was for a rail that would fold against the racks when not in use. They were made according to Human Factors specifications. A pushbutton and spring assembly were installed to allow the hand rail to open and close. This handrail is shown in Figure 26.

MAN/SYSTEM STUDIES

The hand rails were only one of the man/system configurations provided for study. Foot retainers were provided in different configurations throuhout the station. One was a soft foot restraint in the Crew Quarters where toes were put inside a stuffed foot hold. Another was a telescoping adjustable restraint attached to the table in the eating area as shown in Figure 27. There were ridges provided at various places for an Astronaut to temporarily put a foot under to steady himself. These and other studies were supported by Micro Craft for the MSFC man/system engineers.

Color and material were important factors in man/system studies. Racks were painted according to these specifications. Material was installed in the Wardroom area to provide a quiet place for the Astronauts to gather and to baffle the noise from this recreation area from the crew sleeping area.

The exercise equipment was installed for study of the exercise area. Average size maniquins were provided by Micro Craft for the study of fit and function within the modules. The exercise equipment is shown installed within a rack in Figure 28.

A workstation was built for the man/system engineers to study placement of tools, repair techniques, and information transmitted. This work station was fitted within a standard rack, shown in Figure 29. It was wired for lighting and for a working monitor. This task required electricians, welders, metal workers, painters, and assemblers.

SUPPORT OF PAO ACTIVITIES AND MSFC AFFAIRS

Micro Craft supported Public Affairs Office activities and MSFC affairs by maintaining the mockups in a neat condition. The interiors of the modules were maintained in workable condition. Repairs and modifications were done expeditiously. The new requirements for changes were manufactured and installed as needed.

Many important events occurred during this contract, such as the visit by Vice President Bush, Presidential candidate Michael Dukakis, Vice President Quayle, many Senators, Congressmen, Congressional Aids, Presidents of major companies, and many others. Micro Craft furnished support for all these activities as needed. One of these activities is depicted in Figure 30.

Major MSFC affairs included the yearly picnics when the Space Station mockup was open for review, Center Director tours for various visitors, Man/System Review meetings, the U.S. Laboratory Review meeting, among others. Micro Craft provided personnel to prepare for these activities in maintaining, upgrading, and preparing the area.

Figure 26 Hand Rails on Racks

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Figure 27 Telescoping Foot Restraint

Figure 28 Exercise Area

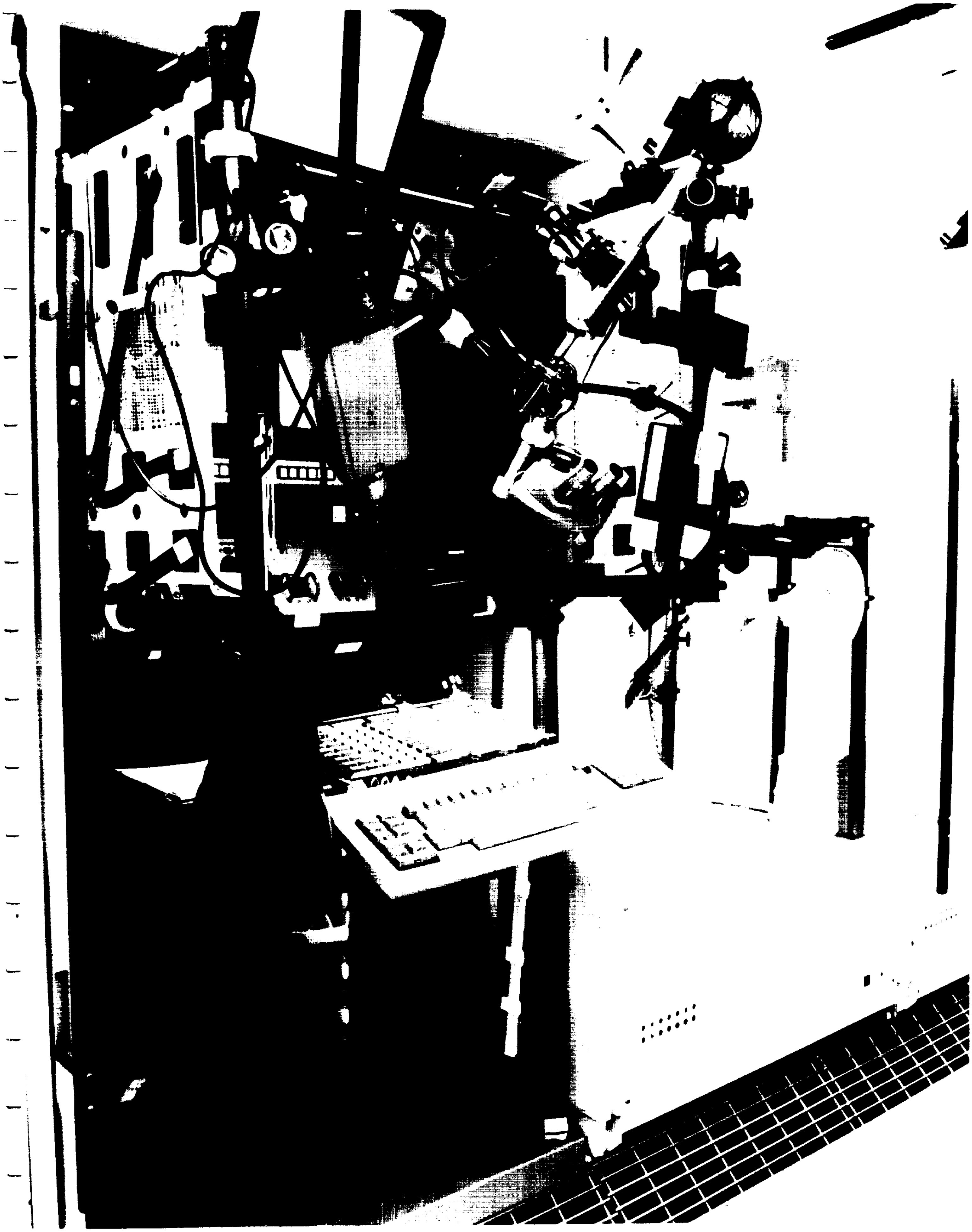

Figure 29 Repair Work Station

Figure 30 Public Affairs Tour for Vice President Quale

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PART TASK MOCK-UPS

A) Spacelab Interconnect

An interesting study Micro Craft supported was connecting the Spacelab to a Space Station docking port. An interconnect was designed and Micro Craft manufactured it and fitted the two Spacecrafts together to simulate docking of the two Spacecrafts. This was an interconnect, fabricated from Graphics Art Board, which allowed a quick study of this activity.

B) High Fidelity Rack Study

Another part task mockup consisted of a section of the Space Station outfitted with a high fidelity rack and stand-off. The standoff was plumbed and wired to the current design. This allowed the MSFC engineers studying rack design to properly evaluate the rack and standoff designs as well as how the plumbing and wiring were run within the standoffs. Also, this configuration allowed for servicing and repair studies to take place, since the rack and standoff were built to exact dimensions and the wiring and plumbing fixtures were exactly fitted. The rack tilting mechanism was also fabricated to specifications as in the drawing in Figure 31.

The rack test bed is a 168" I.D. cylindrical module section, an MSFC 80" and 74.5" racks with standoffs, a Boeing Aerospace Company graphite epoxy 80" rack with aluminum 1-G standoff and a Martin Marietta Company 74.5" rack with standoff, which was not installed in the module section. The MSFC rack was provided with the typical user support equipment and subsystems (i.e. avionic air, TCS, and power converters.) Stud supports were provided. Structural integrity and design attributes were evaluated by the Operation and Utilization Project Office at MSFC. Retractable handrails and fixed handrails were fabricated and both designs studied.

The utilities located at the interface plate were studied for accessibility, easy hookup, hand clearance, and quick verification of utilities (see Figure 32). Utility lines were studies for design so the line could be removed without removing a 44 foot length line or large amounts of standoff structure. Rack connector interface panel concepts were also studied.

Micro Craft provided all the fabrication, installation, upkeep, and technician support for these studies. Micro Craft fabricated the cylinder, floor, steps, racks, standoffs, utility lines, connectors, and interface panels for the MSFC racks, provided the standoff and installation for the Boeing rack. The materials were provided for the project plus engineering, technician, and computer personnel support. All rack study reviews were supported.

C) Robot Study - Georgia Tech Subcontract

Micro Craft sublet a contract to Georgia Tech Research Corporation to support an in-house MSFC study of robot activity within a basic rack. This was for development of a seven degree of freedom small robot arm which could perform laboratory type assist research functions within the internal envelope of a Space Station rack to function in a zero gravity environment. This would provide a small, highly flexible manipulator for

- **Rack Utilities Routing**
- **Rack Attachment**

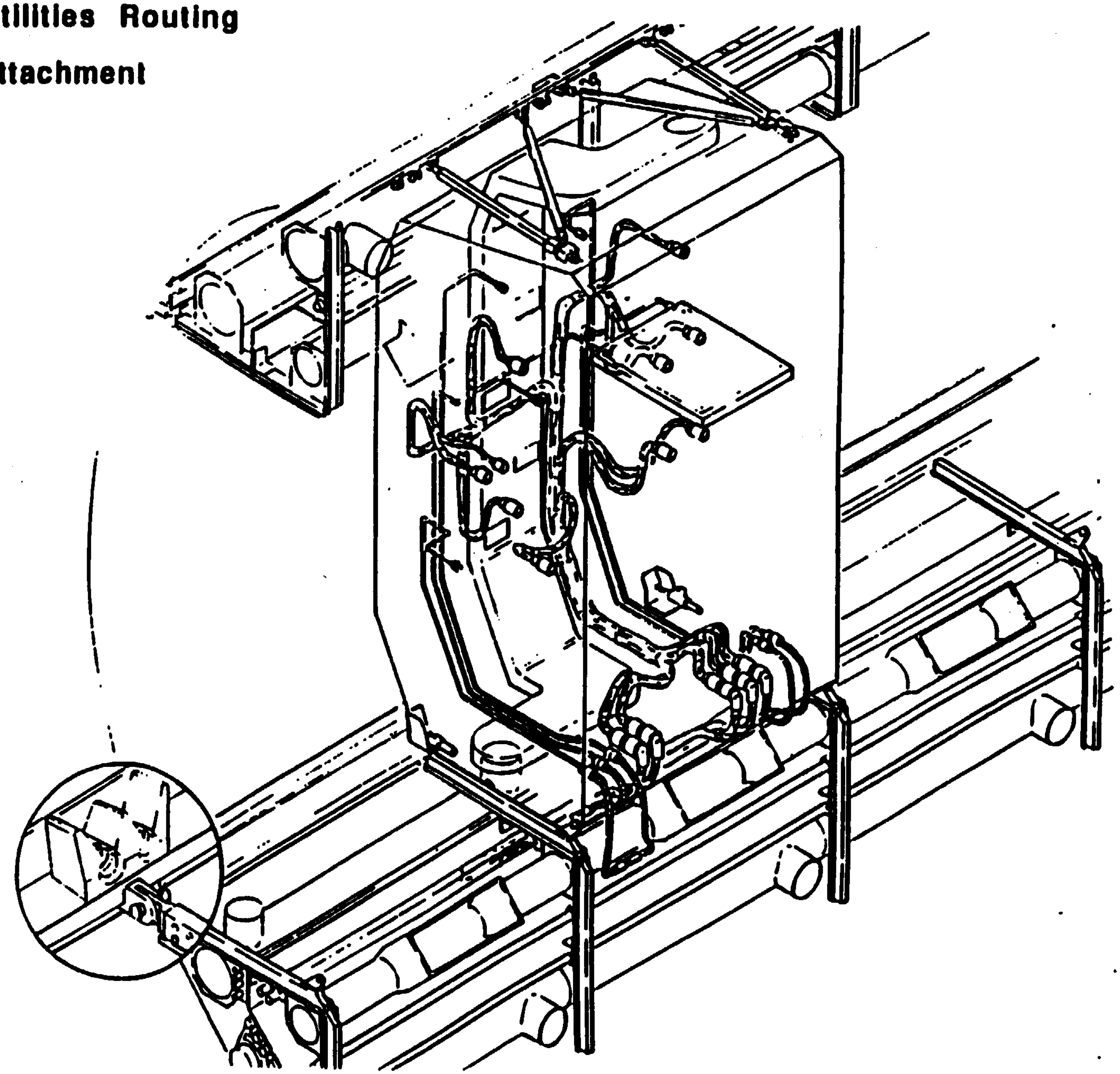

Figure 31 High Fidelity Rack Module Drawing

- **Rack Access/Tilting**

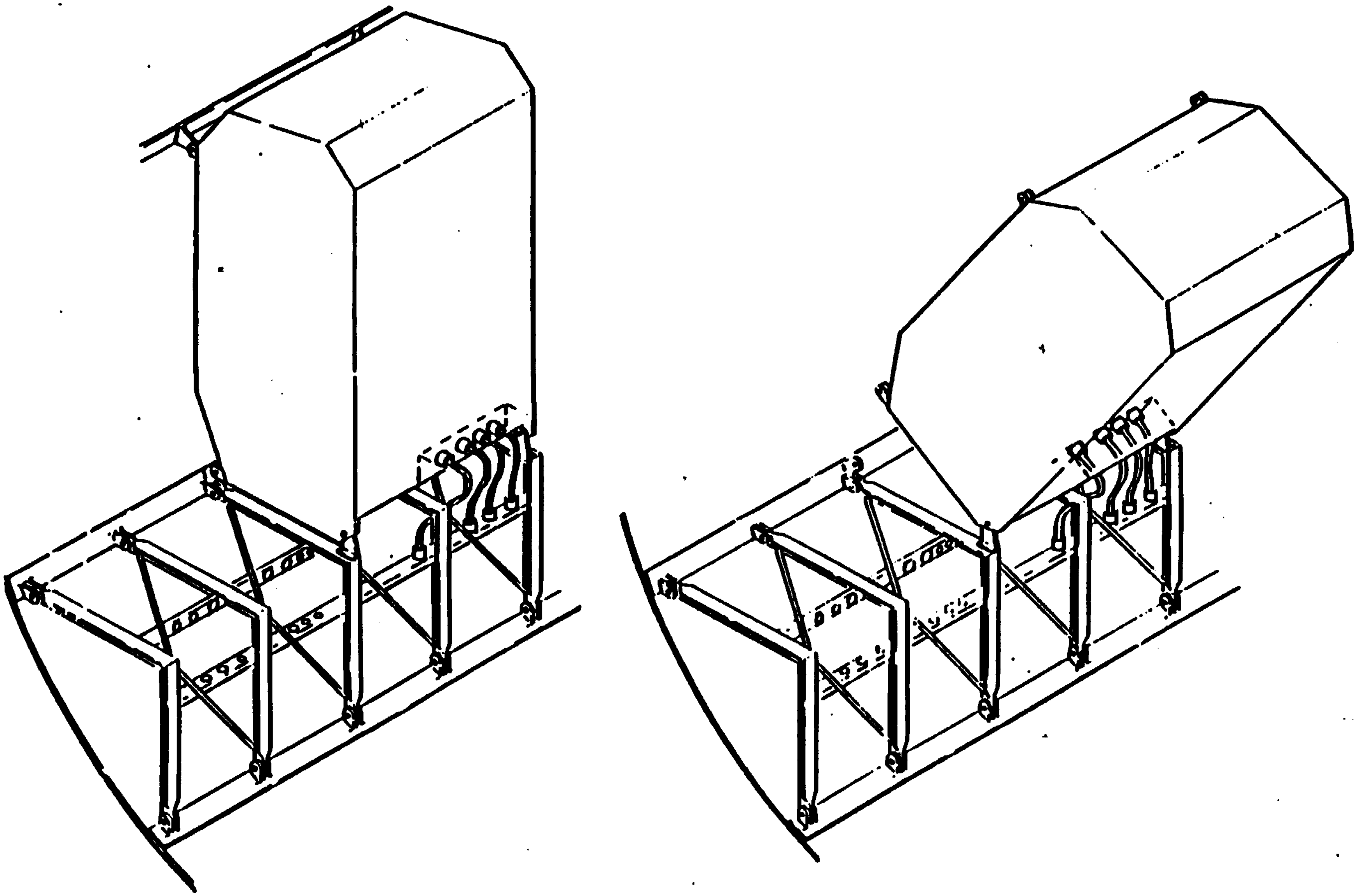

Figure 32 Rack Access/Tilting Drawing

use in the research module with payload capability, high maneuverability, and ability to conform to a highly constrained work envelope. The new design proposed and developed offered 180 degree of pitch and 360 degree of roll, thereby increasing the flexibility of the arm. The backlash was minimized in the joint/gear arrangement. Sensors were added on the arm for feedback to the controller. The arm had incremental encoders as well as force/torque sensors, tachometers, and accelerometers to allow the arm to be more easily controllable. Materials considered to make the arm lighter were composite structures, lighter aluminum or sandwich type structural sheets. An open frame light weight aluminum was finally chosen.

The robot was designed so that all joints moved simultaneously. It was reccommended that a control microprocessor be chosen that would be very fast and efficient to assure smooth movement.

This robot arm was designed and built and demonstrated by Georgia Tech Research Institute under the supervision of Micro Craft engineers along with MSFC engineers. The contract funding ended before a prototype could be built and delivered.

D) Protein Crystal Growth Rack

A rack was built by Micro Craft and a robot arm installed on a platform within the rack for study of a Protein Crystal Growth experiment. This rack, shown in Figure 33 was moved into the Special Studies module (to be discussed later) for the MSFC Preliminary Design Office.

E) Plant Facility Rack

A rack was built by Micro Craft and moved into the MSFC study area to support a study by Alabama A&M University with Ames and MSFC on the possible growth of plants in the U.S. Laboratory of the Space Station. The usage of this rack is shown in Figure 34.

ILLUMINATION MODULE AND SPECIAL STUDIES MODULE FOR MAN/SYSTEM

A module was modified for the Special Studies module for Man/Systems. This included stripping out all wiring, rewiring, putting in new flooring, painting, installing air conditioning and heat, building and installing moveable separation panels, new doors, and steps. Racks were installed for special studies, such as the Protein Crystal Growth Rack and the Robot Rack. This laboratory was used for special part task mockups for Payload Development and man/ system studies, such as acoustics and anthropometrics (the study of human body measurements). Micro Craft provided metal workers, painters, wood workers, electricians, air conditioning and heating technicians and assisted in the interior design of the module as well as outfitting and installing the racks.

A new module was built for the illumination laboratory. This consisted of the design and fabrication of a 20' x 20' x 60' room with a 20' x 60' extended unobstructed adjacent area. This laboratory was designed to test and determine usefullness of various luminaires and illuminated sources by MSFC man/system personnel. The room was designed with special ceiling, floors, lighting, and side walls that would assist in making

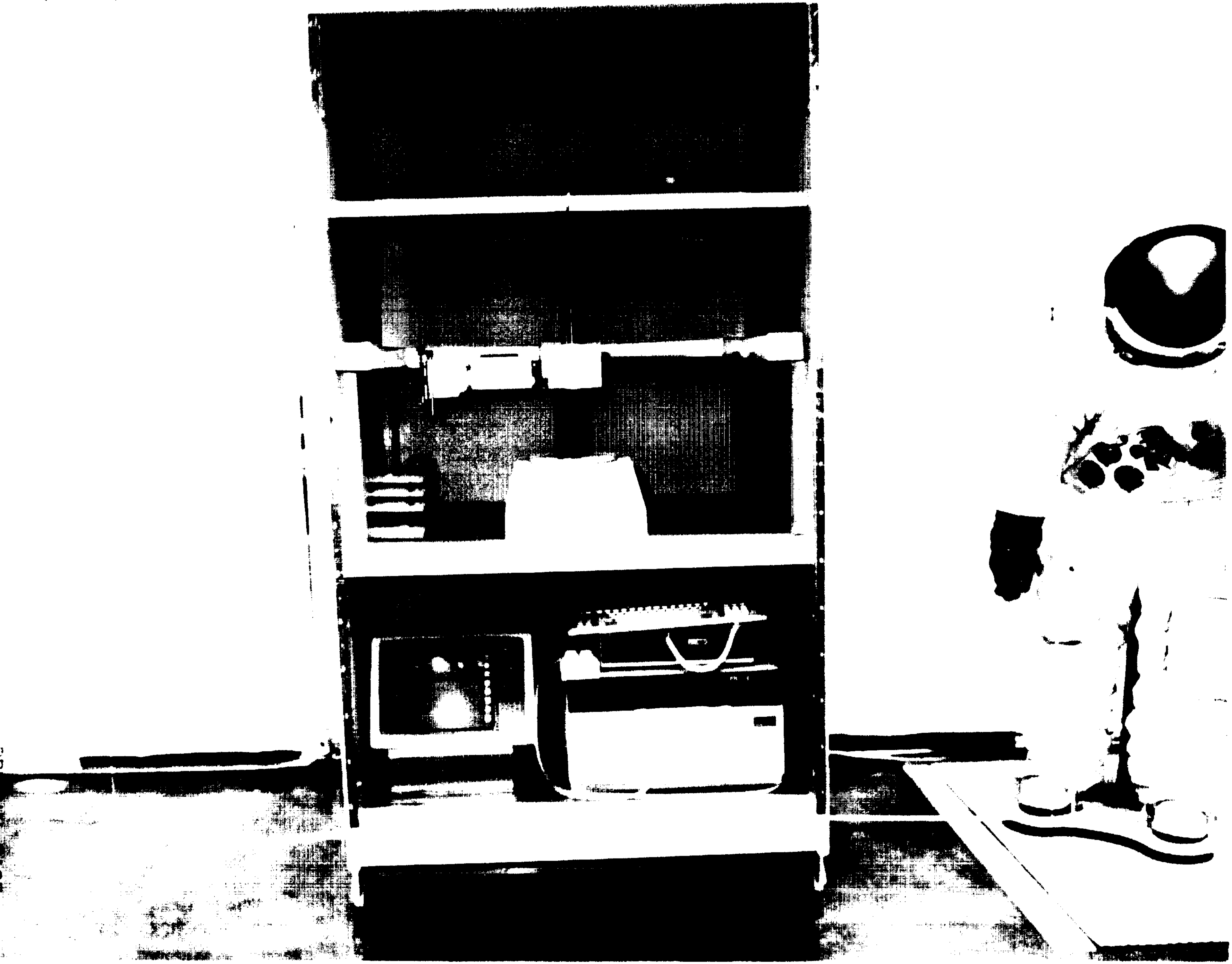

Figure 33 Protein Crystal Growth Rack

Figure 34 Plant Facility Rack

these studies accurate. The extension contained rack faces on standoffs for special studies, and storage areas for material. Light boxes were built, computer hookups and electrical outlets were provided in both areas. Power and air conditioning and heat were installed. Micro Craft furnished metal workers, wood workers, designers, computer engineers, air conditioning and heating technicians, electricians, and painters for this task.

ECLSS AND PMMS ACTIVITIES

Micro Craft began work on the Process Material Management Simulator (PMMS) and Enviornmental Control and Life Support System (ECLSS) in 1986. The PMMS Simulator is a sealed enclosure with one door on the front large enough to accommodate a single Space Station rack. This is shown in Figure 35. This simulator has clearance above, below, front, and rear for servicing the rack mounted experiments. There are provisions for environmental conducting ducts, and electrical, instrumentation, gas, liquid, vacuum, and sample feedthroughs interface with the experiments. The Experimental rack is a prototype of the design currently used in the MSFC mockup.

The supporting facility provided for the PMMS Simulator controlled environment, gas, and liquid transfer systems, high and low vacuum systems, electrical power, control, instrumentation, gas sensor, data acquisition, and process fluid storage.

Micro Craft povided all labor, services, construction, tool, fabrication, cleaning, testing, and equipment for designing and preparation of complete shop drawings and shipping to MSFC in Huntsville, Alabama in strict accordance with drawings and specifications. Micro Craft provided:

1) A PMMS enclosure for a prototype rack with the required electrical and mechanical feed throughs to accommodate an MSFC designed prototype rack.

2) An MSFC designed prototype rack such as the one in the MSFC mockup.

3) Interface hardware, supply, and return ducts for connecting the PMMS enclosure to the environmental chamber.

4) All drawings, calculations, and test certifications were provided to MSFC upon delivery of the PMMS enclosure, prototype rack, and simulator adapter/interface hardware.

5) Test support for all simulator activities.

TEST SUPPORT

Micro Craft designed and fabricated mechanical (pneumatic and fluid), electrical and instrumentation, consoles and terminals with design engineering, sheetmetal, welding, machine shop support personnel, and on-site experienced test operating personnel.

Micro Craft provided planning, design, fabrication, and installed all electrical, mechanical, instrumentation, and sensor systems required for the PMMS simulator test

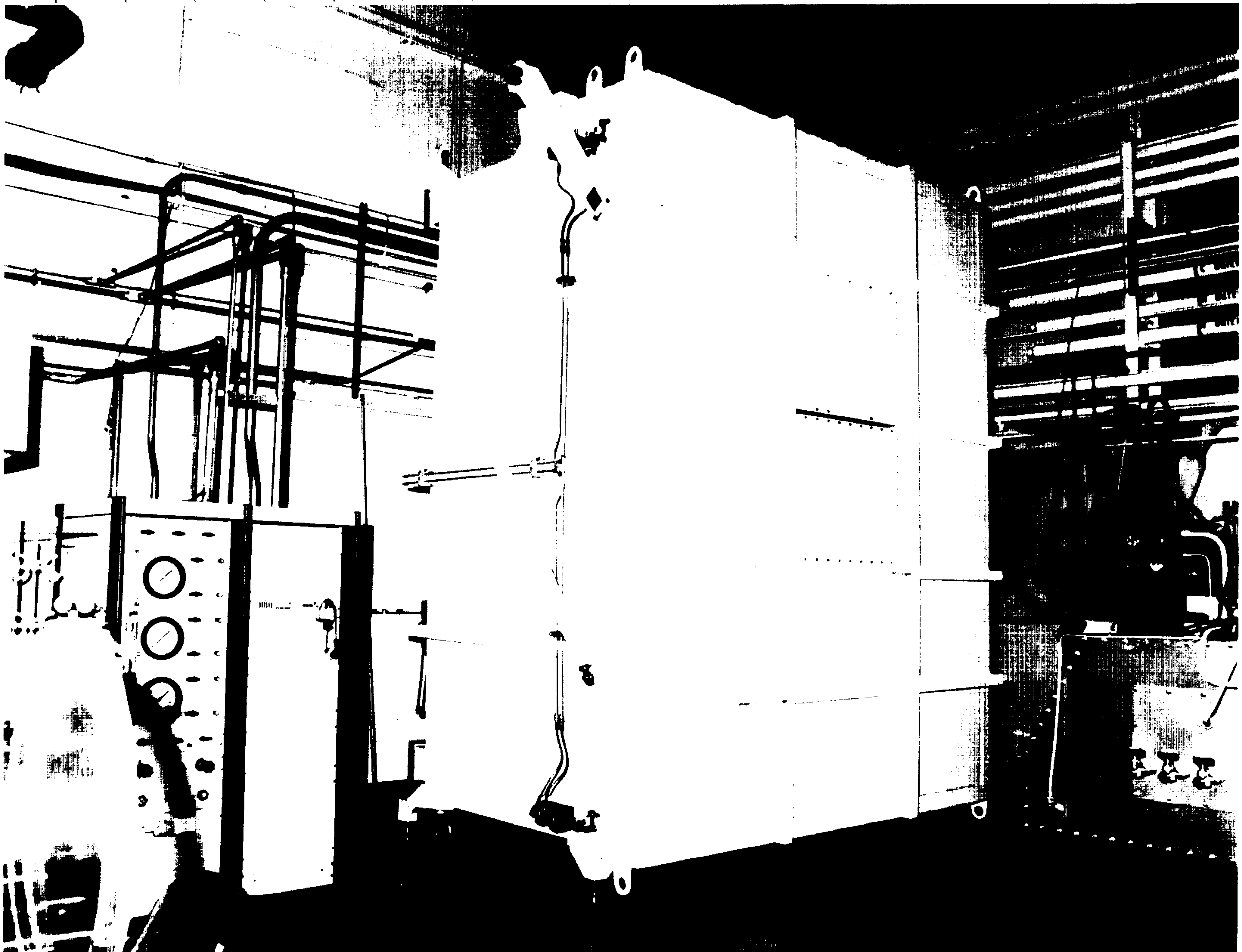

Figure 35 PMMS Enclosure

program. Personnel procured pressure transducers, flow meters, temperature sensors, monitoring sensors for gaseous hydrogen, oxygen, carbon dioxide, and methane. In addition, pressure gauges, vacuum gauges, level indicators, pressure switches, connectors, wire, switches, resistors, potentiometers, etc., conditioning electronics equipment for instrumentation, software, electrical, and mechanical racks, pumps, regulators, storage tanks, traps, tubing, fittings, flex hose, valves (solenoid, hand, metering, relief, chech, etc.), vacuum pumps and ancillary equipment, quick disconnects, power supplies, data acquisition system and supplies, filters, chemicals, bottled gas, adsorption units, spare parts for repairs, nuts, bolts, brackets, clamps, gaskets and seals, plus special equipment required to support the test program.

Micro Craft also provided the special laboratory equipment and services to identify and detect for real time assessments of liquids, gaseous, particulate samples, and specimens, including fecal matter, urine, waste water, condensate, hazardous gases, liquids, and solids. Long time storage, transporting, and inventory control of these samples/specimens were provided. Also, on-site handling, shipping, storage, and inventory control of sensitive items, such as GFE (Government Furnished Equipment) experiments, replacement parts for such, critical hardware and long lead time items critical to the ECLSS/PMMS test program were provided, as well as repairs and maintenance of major GFE and associated peripheral equipment.

Micro Craft provided support for troubleshooting of equipment, performing periodic maintenance, installing electrical and mechanical hardware, components, and systems. Personnel prepared test setups, operated test systems, collected and reviewed test data. Mechanical and electrical design were provided to support the aforementioned facilities and disciplines. Test procedures were developed, including facility activation, test operations, and standard operating procedures by on-site personnel.

SAFETY REVIEWS

Micro Craft supported pre-operational safety review validations, test readiness reviews, operational readiness reviews, and provided the required procedures, hazard analyses, test facility and equipment information required.

PMMS ACTIVITIES

Micro Craft began work on the Process Material Management System early in the program. These activities began with the PMMS Simulator in 1986. The PMMS Simulator was a sealed enclosure with one door on the front and was large enough to accomodate a single Space Station Rack and all support equipment. The simulator was designed to house a Space Station Quality Glovebox, shown in Figure 36, for use in various experiaments and to provide a maximum of 10 inches water gage internal positive or negative pressure to allow experimentation with minimally hazardous material. Feedthroughs were provided in the simulator for HVAC, electrical, instrumentation, various gases, vacuum and sampling interfaces.

Micro Craft furnished all design, engineering and construction drawings for the fabrication of the PMMS Simulator. In addition, Micro Craft procured a Space Station Quality Glovebox for use in the simulator. The glovebox was designed with a nuclear grade material handling system and feedthroughs for electrical, instrumentation, various

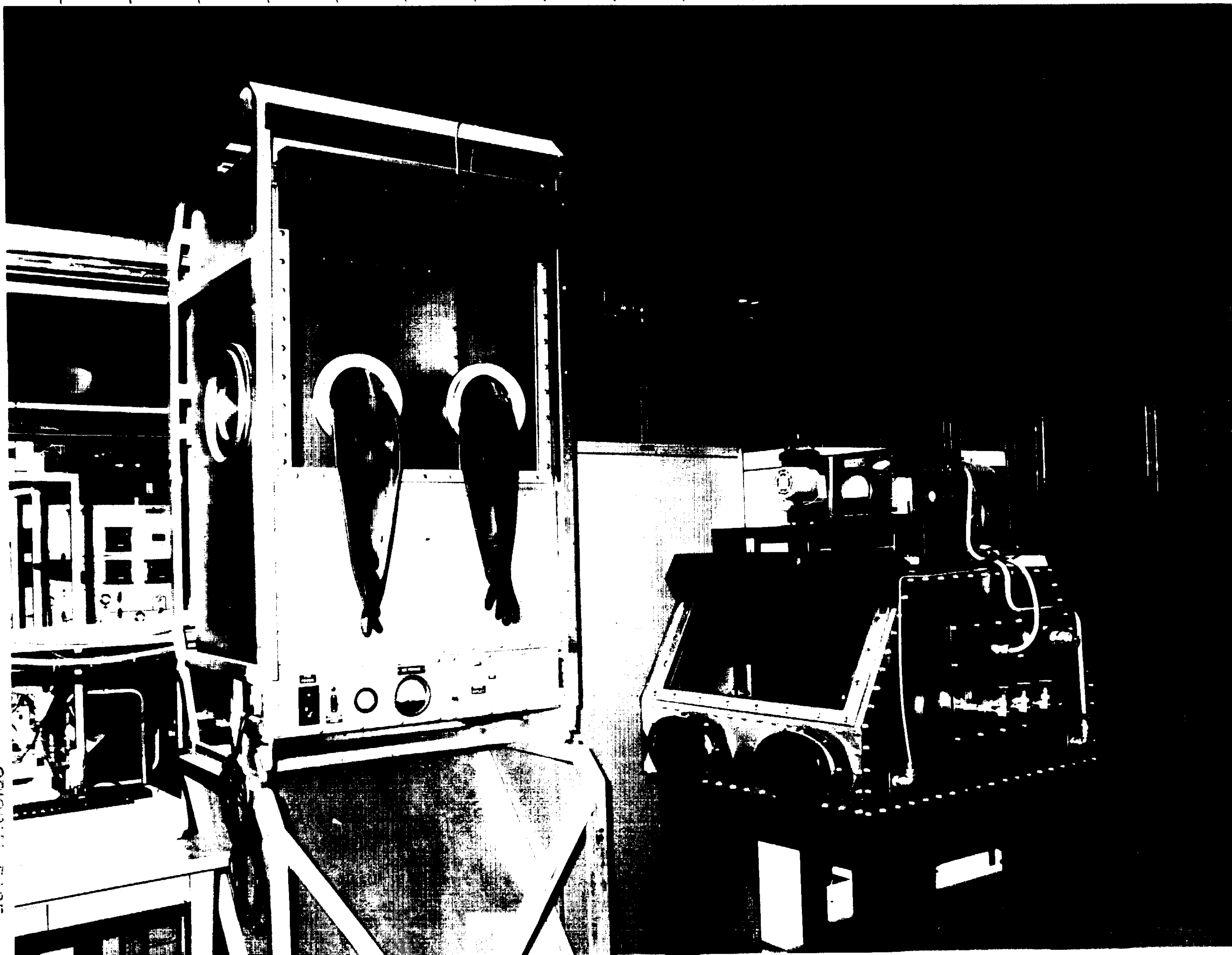

Figure 36 Glove Box Installed in a Mockup Rack on a Standoff

gases, vacuum, and sampling use.

FACILITY SUPPORT

In order to support the various PMMS testing plans, Micro Craft designed, engineered, procured, and assembled a facility support area in the North Bay of Building 4755. This facility support area was designed to provide nitrogen, oxygen, and helium gases, 24v and 120v power, data acquisition (using CIM-PAC), and control (using PLC) for all tests. All of the support equipment was mounted in 19" wide racks with standard tubing connections for the gases and vacuum and terminal strips for the power and data acquisition. Various types of instrumentation, including flowmeters, pressure gauges, thermocouples, and gas detectors, along with controls for valves and pumps were included in the design.

PMMS TESTING

The support for PMMS testing included writing and reviewing test procedure, safety and hazard analyses, test bed design and fabrication, test bed installation, test operations, and writing test reports. Micro Craft provided engineers and technicians in suport of these activities.

The tests supported under the PMMS program included "Quick Disconnect Leak and Inclusion" and "Reverse Diffusion Under Constant Pressure". Other tests were planned by NASA but, due to budget constraints, were never completed. These include glovebox glove wear and abrasion and ultra pure water degradation. All of these tests were acted upon to some extent by Micro Craft before cancellation.

ECLSS ACTIVITIES

The involvement with the PMMS activities lead to an involvement with the Test Lab Division support of the Space Station Environmental Control and Life Support System (ECLSS). The Micro Craft support for the ECLSS test program started with the Phase II bench testing of the various air- and water-side subsystems. In these Phase II operations, each subsystem was operated with facility interfaces to determine the actual nominal operation.

At the completion of the Phase II activities, Micro Craft personnel was immediately shifted to the Phase III testing. To support the Phase III test plans, a Core Module Simulator, shown in Figure 37, was designed and specified by Micro Craft and built by Chicago Bridge, Inc. This simulator was a full size Space Station module and was designed and tested for an internal pressure of 0 to 25 psia. With few exceptions, all subsystems for Phase III testing were installed in the simulator. This is shown in Figure 38. The Phase III test plan included both air-side and water-side testing. The air-side testing was the "Simplified Integrated Test" conducted in May and June, 1989. The Water-side Tests were conducted starting in April, 1990.

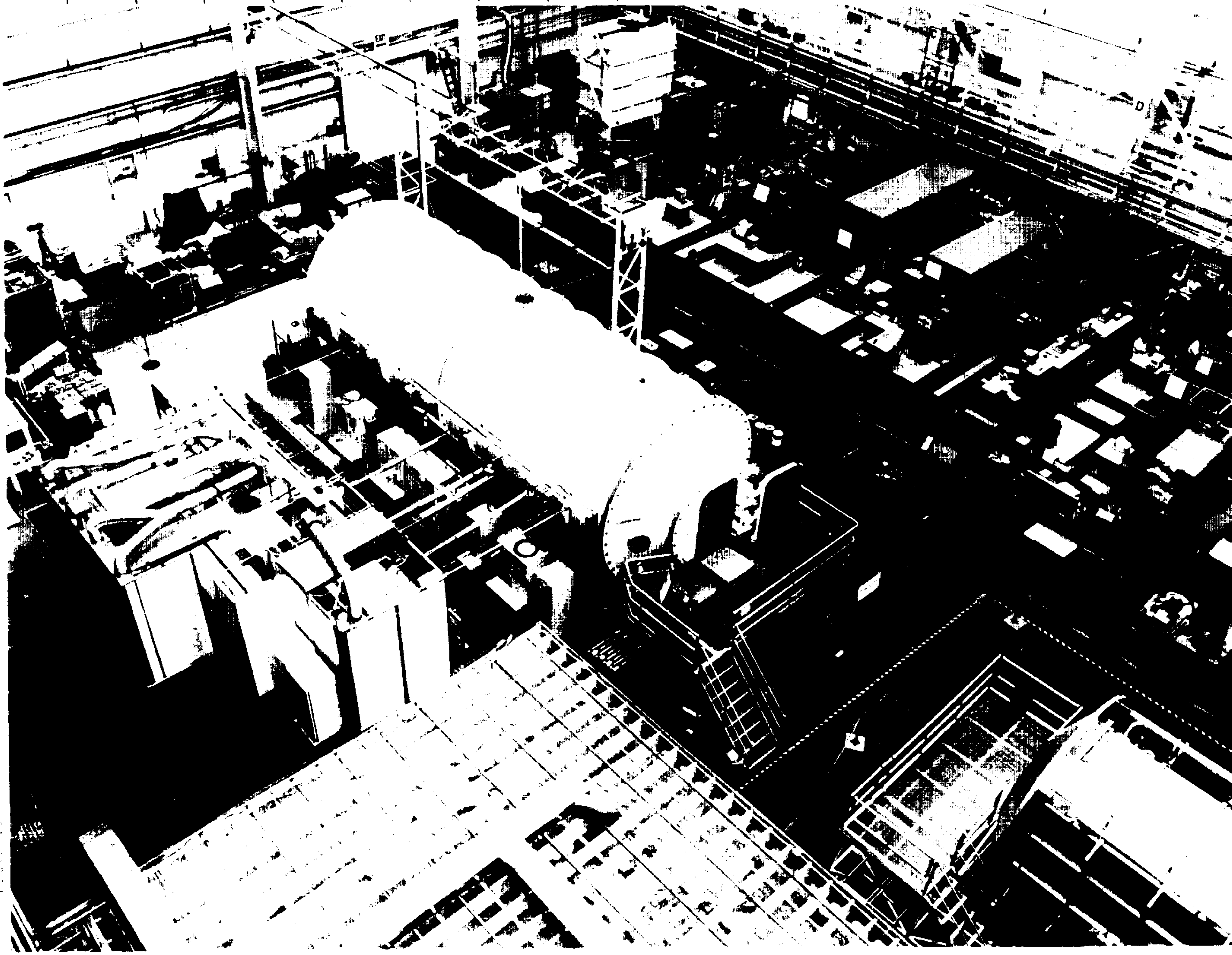

Figure 37 Core Module Simulator

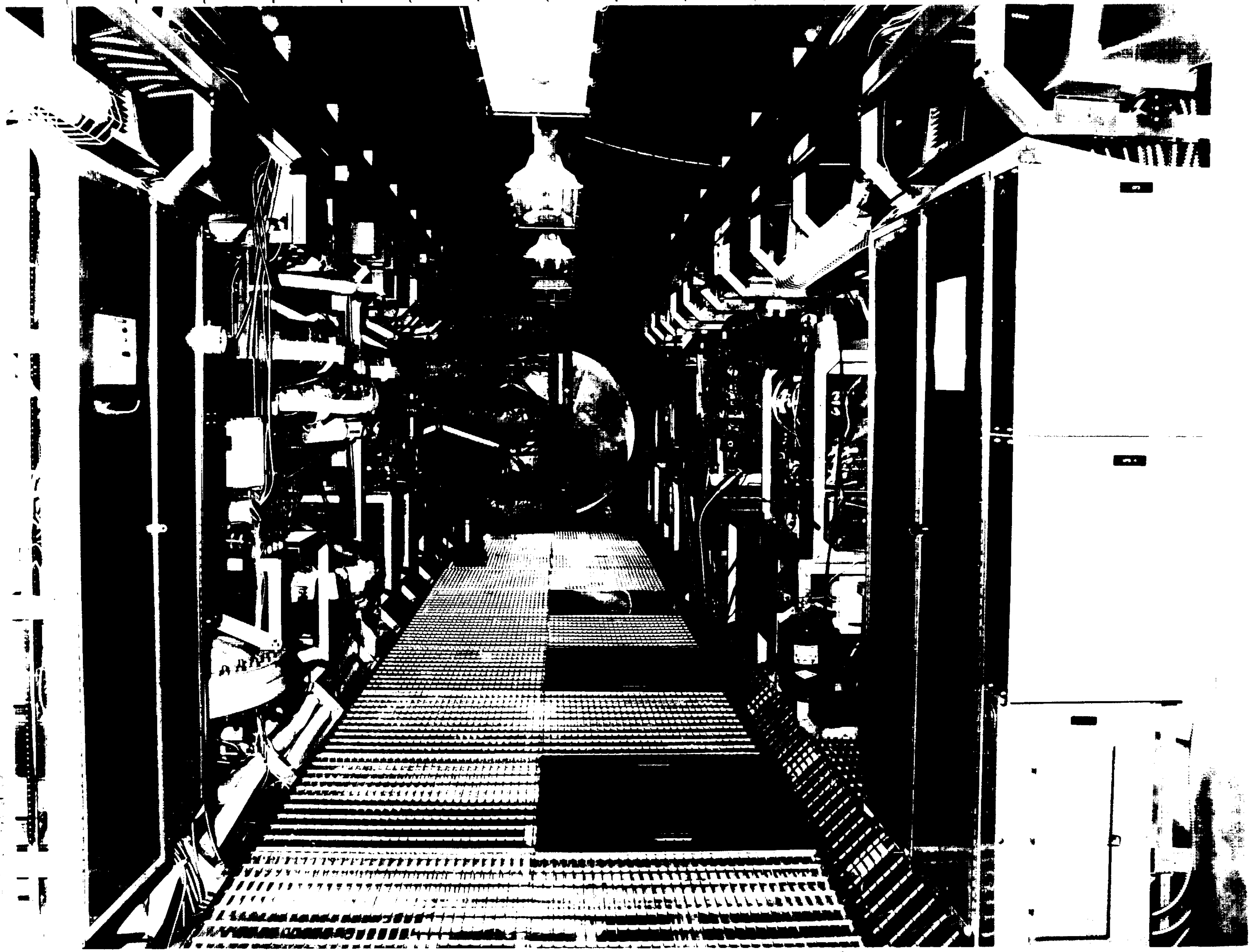

Figure 38 Core Module Simulator Internal

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The support for the Phase III testing included the following areas:

1. Design and layout of the test bed configuration.

2. Selection, procurement, and installation of all test bed electrical and mechanical, and instrumentation components. This included tubing, valves, various sensors (dew point, percent gas monitors), various transducers (gas flow, air flow, temperature), electrical power and conduit.

3. Design and installation of the CMS thermal control system. This was a pseudo-space station system consisting of inlet HEPA filters, fan, cooling coil and air distribution ductwork and registers.

4. Design and programming for the system control software. For this test, Programmable Logic Controller (PLC) was utilized. This software allows for control of all actuated vavles, blowers and indicator lamps.

5. All maintenance and trouble shooting to the test bed and facility support was provided by Micro Craft.

ACOUSTIC LEAK DETECTOR

Another of the early activities associated with the CMS was the Acoustic Leak Detection System (ALDS). The ALDS consisted of sensors and software designed to locate air leaks using changes in the acoustic characteristics of the CMS. Micro Craft wrote and issued an RFP for the project and a contract was awarded to NDE. The contract required NDE to characterize the acoustic signature of the CMS and to provide all hardware and software necessary to complete the ALDS. The final product was delivered in late 1990.

CONCLUSION

This contract provided an opportunity for Micro Craft to be involved in the early develpment of the Space Station Freedom. This development included many important activities. Micro Craft built the modules for the mockup which continues to be the development tool for design of the modules as well as the interiors. It has been used for man system studies also. The mockup is a very important system for informing the general public and many VIP's on the development of the Space Station Freedom. The PMMS and ECLSS simulators have provided the test bed for minimally hazardous material, air, and water-side subsystems. Micro Craft supported all phases of the tests.